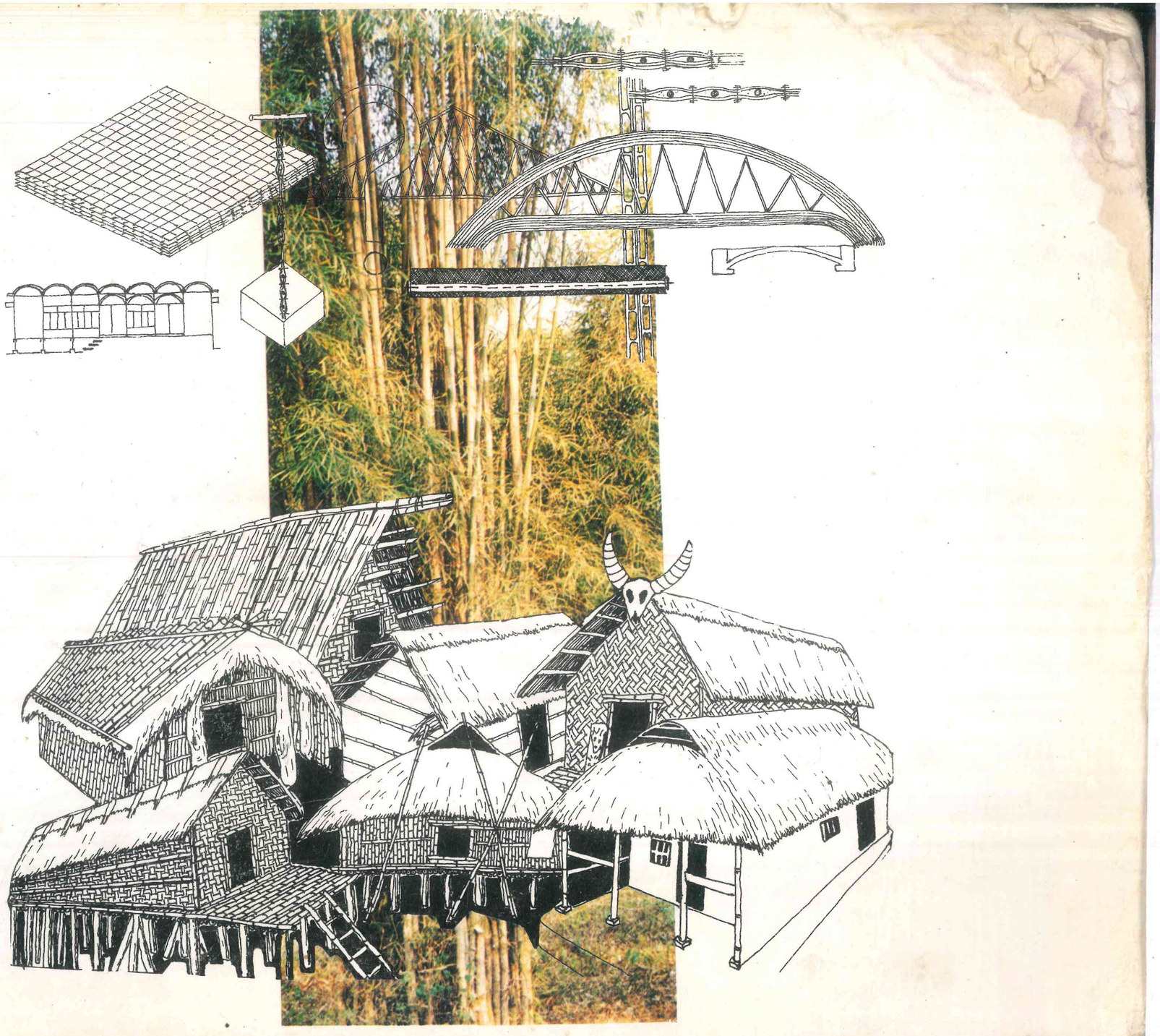
BAMBOO IN THE FIELD OF CONSTRUCTION IN NORTHEAST INDIA

bipul kumar das

TECHNICAL PAPER NO : 1

C.B.T.C.
CANE & BAMBOO TECHNOLOGY CENTRE
GUWAHATI : ASSAM : I N D I A



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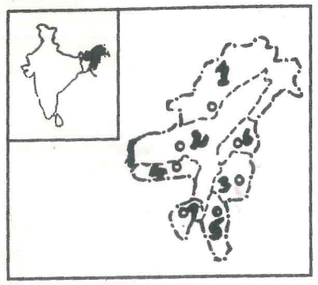

(1) ARUNACHAL PRADESH
(2) ASSAM
(3) MANIPUR
(4) MEGHALAYA
(5) MIZORAM
(6) NAGALAND
(7) TRIPURA

BAMBOO IN THE FIELD OF **CONSTRUCTION** IN NORTH EAST INDIA

BIPUL KUMAR DAS

ARCHITECT,
DESIGN NUCLEUS
GUWAHATI. ASSAM

TECHNICAL REPORT NO. 1
C. B. T. C.
CANE AND BAMBOO TECHNOLOGY CENTRE
GUWAHATI. ASSAM. INDIA

CANE AND BAMBOO TECHNOLOGY CENTRE
(CBTC)

COVER :
Design lay-out :
Bipul Kr. Das

Drawn :
Chetan Sharma
&
Mobina Saikia

CORRESPONDENCE :

- Cane & Bamboo Technology Centre. Opp. Tea Auction Centre Dispur, Guwahati - 781006 INDIA
- Bipul Kumar Das By- Lane 11 west R. G. Barua Road Guwahati - 781024, INDIA

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Cane and Bamboo Technology Centre

From times immemorial to the present day, cane and bamboo have formed an integral part of the lives of the people in the North Eastern Region. Bamboo is used in myriad ways to make several articles, implements etc. Generally people make those things which are required in their day to day lives.

Bamboo handicrafts and furniture is produced throughout the North East. Productivity is low because of the limited knowledge, lack of skills and basic tools. Quality is generally poor due to several reasons : bamboo used for handicrafts and furniture is not mature enough, bamboo is not treated, improper handling, lack of knowledge about jigs, poor jointing and lack of finishing materials and skills. It is in this context that the concept of a specialised institution dealing solely with cane and bamboo was conceptualised.

Thus, a **Cane and Bamboo Technology Centre** (CBTC) came to be set up at Guwahati with the aim of identifying and disseminating technologies for economic enhancement of craftspeople and small and medium-scale entrepreneurs and also to enhance the skills and quality of goods produced in the Cane and Bamboo sector of North East India. Another important aim of the CBTC is to strengthen the capacity of existing institutions through networking and by linking them with specialised institutions in India and abroad.

The United Nations Development Programme (UNDP) has committed approximately $ 1.4 million Technological upgradation and Networking for the Cane and Bamboo Project. The Department of Science and Technology (DST), Government of India is the Executing Agency for the project and has therefore overall responsibility for the Programme to the Government of India and the UNDP. The United Nations Industrial Development Organisation (UNIDO) is the assigned Implementation Agency, while the North Eastern Development Finance Corporation Ltd. (NEDFi) is the Field Implementation Agency, responsible for project activities through the Cane and Bamboo Technology Centre.

The CBTC intends to promote employment and income generation through making relevant industrial and craft technologies and business opportunities more accessible. The core of the project strategy is the strengthening of the institutional structure of resource centres in the region and upgrading the skills of entrepreneurs, trainers and leading craftspeople to achieve the widest possible dissemination of the technologies and skills needed for managing, marketing and adding value to these hitherto under-utilized resources. In order to achieve this objective, the identified centres will be equipped with appropriate resources (information technology and electronic communication facilities, tools and equipments for demonstration purposes, training facilities, etc.) under the overall co-ordination of the DST.

It is also anticipated that a long-term association will be established with the International network of Bamboo and Rattan (INBAR), based in Beijing, to provide strategic and specific technical inputs.

The CBTC has now embarked upon hosting a training workshop on Affordable Bamboo Housing in Earthquake Prone Areas in collaboration with the International Network for Bamboo and Rattan (INBAR) and the Government of Mizoram at Aizawl from 29th October, 2001 to 11th November, 2001

On the eve of hosting the Training workshop on Affordable Bamboo Housing in Earthquake Prone Areas, the CBTC is bringing out this Technical Paper which is the result of the untiring efforts of Arch. Bipul Das, who is extensively involved in constructions using Bamboo.

Kamesh Salam
Project Co-ordinator
C.B.T.C.

FOREWORD :

While it is an endeavour on the part of C. B. T. C. to bring in developed bamboo technology from outside to the North East India it is also the aim of C.B.T.C. to support local research and developmental projects to work towards upliftment of bamboo technology. Bamboo building technology is one such area.

As a first step towards it's goal C.B.T.C. found it necessary to gather knowledge about what N.E. India has traditionaly in the area of bamboo housing or what has been the effort, if any, towards its development or what does N.E. India has in the name of bamboo resources. It is in a way, recording of informations to form a basis for future action plan of C.B.T.C. in the area of bamboo building technology.

And, thus is when C.B.T.C. stumbles upon my work — i.e. — a study done by me with the aim to find out a system of building construction with bamboo as the principal material. Interestingly the study was done 31 years ago (1970-71) as a dissertation project in final year of architecture course and that was much before INBAR came in to existence. My works also include an experimental residential building with extensive use of bamboo constructed 28 years ago (1973) where I lived for 25 years. The aftermath of success in this project is the use of bamboo roof-cum-floor system in a R.C.C. framed structure again for self occupation done recently i.e. in 2000.

However C.B.T.C. has found relevance of my studies on bamboo even today and has entrusted me, with whatever knowledge I have about bamboo, to start with the process of introducing the N.E. India into the international stream of bamboo activists with whatever resources we have to be a part of it to share ideas, views and activities.

Thus is this book.

Part II of this book has been included to promote ideas for the cause of bamboo.

Hope this book will carry atleast some message.

Bipul Kumar Das
10/10/01

ACKNOWLEDGEMENT :

A moment to remember now is when Mr. Swapanil Barua, Deputy Commissioner, out of the blue, walks into my chamber and tells me about C.B.T.C. and also about his mentioning me to them. Second thrilling moment for me is when Mr. A. K. Absar Hazarika, Deputy Commissioner, kamrup and the then General Manager of Spl. Projects. NEDFi and a very much part of C.B.T.C., meets me in my chamber on 14th March '01 to witness my dissertation work on study of bamboo and calls me over to C.B.T.C. the next day. Mr. Kamesh Salam, Project Co-ordinator of C.B.T.C. is the next person whom I have met and who has offered me tremendous support to carry forward R & D projects on bamboo in constructional area including this book to air my views and get hooked, if at all, into the world of bamboo again.

My sincere thankfulness is extended to Mr. Mukul Mahanta, engineer, for encouraging the publication of my work. I am also thankful to Chetan, the artist from Manipur for helping me with the traditional housing and joinery sketches etc. and Mr. M. N. Upadhyay, engineer, for working out engineering calculations.

And, of course, Mobina Saikia, my assistant, who has been offering constant support with technical drawings, sketches and with valuable supervision on the execution of experimental models in the studio that have been included in this book. Atul Bora, engineer, has helped me with fabrication of the metal parts of my experimental models.

Bipul Kumar Das
10-10-01.

CONTENTS : PART - I

CONTENTS : PART - II

PART - I

EXCERPTS FROM THE DISSERTATION WORK :

As has been said earlier in the foreword, the following plates have been reproduced in a reduced size, from the original works which are fully handwritten & drawn. The work was done 31 years ago when the awareness about bamboo was in a very low key, much lower than it is to-day, and the menace of deforestation was yet to hit the exvironment globally.

The study must be seen in the light of work done by an undergraduate student with the limitation that it was to be carried out in parallel to the regular study and without access to laboratory testing of building materials. Thus the study was based on pure observations clubbed with reasoning and logic. The concept forwarded at the end of the study was without field test but based on simple mathematical calculation and logic. The conclusions drawn 30 years ago still hold good for the N.E. atleast to-day.

It may be noted that N.E. India of today was undivided Assam of that time which the study mentions as the area of work.

THIS THESIS HAS BEEN PREPARED FOR THE PARTIAL FULFILMENT OF THE REQUIREMENTS TO OBTAIN THE BACHELOR DEGREE IN ARCHITECTURE FROM M.S. UNIVERSITY OF BARODA.

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c STRENGTH OF BAMBOO (D. STRICTUS). 'INDIAN FOREST RECORDS' (N.S.). TIMBER MECHANICS. VOL_1. NO. 1.
d ANATOMICAL FEATURES OF BAMBOO. by_ S.S. GHOSH AND B.S. NEGI. F.R.I. DEHRADUN.
e RESEARCH REPORT ON T.C.B.C. by _ N.J. MASANI AND B.C. DHAMANI. F.R.I. DEHRADUN.
f TECHNO-ECONOMIC SURVEY OF ASSAM. by_ N.C.A.E.R. NEW DELHI.
g A HAND BOOK FOR ASSAM ENGINEERS. by_ R.M. NATH.
h PHILOSOPHY OF STRUCTURES. by_ E. TORROJA.
J HAND BOOK OF RURAL HOUSING AND VILLAGE PLANNING. by. N.B.O. N.DELHI. BUILDING MATERIAL P35

ACKNOWLEDGEMENT DUE TO

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MR. K. SURAPPA.	dept. of structural engg.	M.S.U. BARODA.
MR. N.J. MASANI.	director, timber engg. dept.	F.R.I. DEHRADUN.
MR. B.C. DHAMANI.	research assistant. t.e. dept.	F.R.I. DEHRADUN.
MR. S.C. BHUYAN.	experienced cultivator.	DEKARGAON, TEZPUR.

BY

DAS. BIPUL KUMAR. FINAL YEAR OF B. ARCH. COURSE. SESSION 1970-71.

A SYSTEM OF BUILDING CONSTRUCTION WITH BAMBOO AS THE PRINCIPAL MATERIAL.

PART ONE ⟹ READING OF THE MATERIAL.

PART ONE CONTENTS

THE WORDS PREFATORY.

BAMBOO IS AS OLD AS TIMBER AND ONE OF THE **NATURE'S OLDEST GIFTS TO MANKIND.**
SINCE MAN CAME OUT OF THE CAVE AND STARTED THE MAKING OF SHELTERS FOR PROTECTION FROM NATURAL CALAMITIES MANY MATERIALS LIKE TIMBER, EARTH AND STONE HAVE GAINED A CONSIDERABLE UPLIFTMENT IN THEIR RESPECTIVE USES. CHRONOLOGY SUPPORTS IT. BUT BAMBOO A MATERIAL OF GREAT POTENTIALITY AND MUCH PROMISES HAS REMAINED **UNNOTICED, UNCARED** AND **NEGLECTED.** UNNOTICED ARE ITS HIDDEN QUALITIES, UNCARED IS ITS BEHAVIOUR AND NEGLECTED IS ITS GREAT POTENTIALITY. NATURE GAVE TO HER HEART'S CONTENT BUT WE FAILED TO TAKE. IN A NARROW SENSE THE MATERIAL HAS NOT BEEN PROPERLY EXPLORED. THE MASS MISUSES WITH A VERY LITTLE GOOD USES TO BALANCE IT COMPELS ONE TO SAY—THE **USE IS MISUSE** AND THE **CONVERSION IS WASTEFUL.** SO THE POTENTIALITY IS UNREVEALED AND THE STATUS IS GONE! BUT **WHY?**

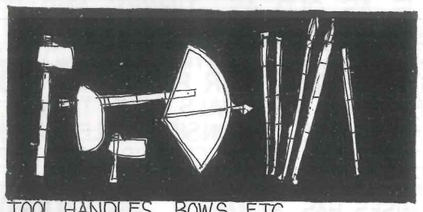
NOW HERE ARE A LITTLE **EXPLORE TO THE WHY**, A **TRY** TO SHOW THE VERSATILITY HIDDEN AND A **HELP** GIVEN TO THE MATERIAL IN GETTING ITS STATUS WHICH IT HAS BEEN DEPRIVED OF.

THE ULTIMATE AIM TO INTRODUCE A **SYSTEM OF BUILDING CONSTRUCTION IN BAMBOO AS THE PRINCIPAL MATERIAL** WHICH WILL HAVE ITS OWN GRAMMAR LIKE A NEW LANGUAGE.
ASSAM HAS THE LARGEST BAMBOO RESERVE COVERING ALMOST ALL THE VARIETIES AVAILABLE IN INDIA. MOREOVER, CLIMATE OF ASSAM IS BEST SUITED TO BAMBOOS, HENCE MOST ECONOMICAL & FRUITFUL IMPLEMENTATION OF THIS BUILDING SYSTEM WILL BE IN ASSAM. IN STUDYING A MATERIAL LONG TERM OBSERVATIONS ARE NEEDED. THIS THESIS THOUGH WRITTEN IN ONE ACADEMIC YEAR'S TIME THE OBSERVATIONS DESCRIBED HERE ARE THE RESULT OF LONG TERM EXPERIENCE WITH THE MATERIAL FOR BEING ALWAYS VERY CLOSE TO IT. THUS AFTER A CONSIDERATION GIVEN TO ALL THESE, **LIMITATION** HAS BEEN PUT TO THE STUDY OF MATERIAL AVAILABLE IN THE STATE OF ASSAM

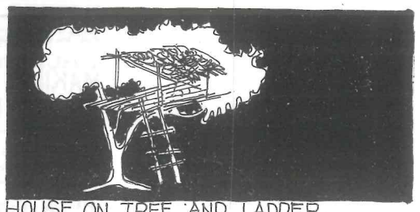
A SYSTEM OF BUILDING CONSTRUCTION WITH BAMBOO AS THE PRINCIPAL MATERIAL

1

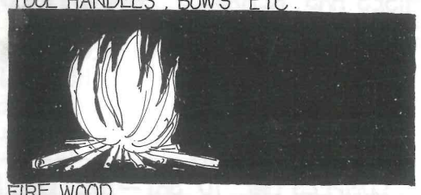
DEVELOPMENT IN THE UTILITY PATTERN OF BAMBOO.



TOOL HANDLES, BOWS ETC.



HOUSE ON TREE AND LADDER.



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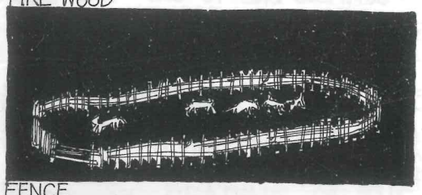

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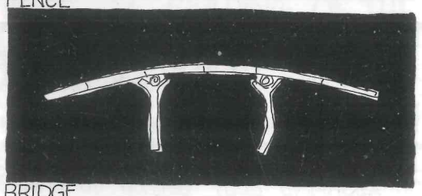

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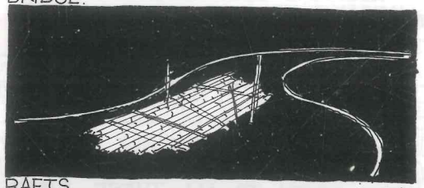

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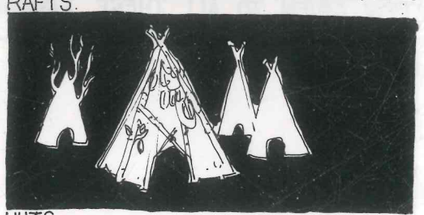


HUTS

IN THE PAST.

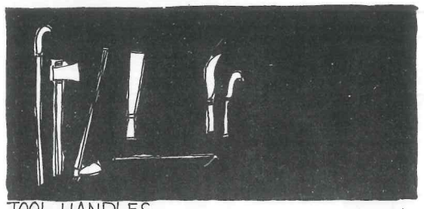
UTILITY OR THE USE OF A MATERIAL IS DIRECTLY CONNECTED TO INTELLIGENCE OF MAN WHICH IN TURN IS CONNECTED TO HUMAN EVOLUTION. SO NATURALLY THE UTILITY PATTERN IN THE EARLY DAYS IS IMMATURED AND CRUDE AS COMPARED TO TO-DAYS. MOREOVER, **UTILITY DEVELOPES WITH EXPERIENCE.**

IN NATURAL FORM BAMBOO IS HANDY AND SHAPING OF IT IS MERELY CUTTING OR BREAKING IN LENGTHS. SO THE NOMADIC PEOPLE FOUND IT USEFUL IN MAKING THE TOOL HANDLES AND LATHAL WEAPONS. THUS BAMBOO WAS USED AS HANDLES OF AXES, BIG JAVELLINES, ARROWS ETC. ITS ELASTICITY OR FLEXIBILITY GAVE RISE TO THE IDEA OF BOWS AND ARROWS. ITS EASY BURNING MADE IT FIREWOOD. BAMBOOS COULD EASILY BE DRIVEN INTO THE GROUND. SO BAMBOOS FOUND THEIR POSITIONS IN FENCES FOR THE PROTECTION OF ANIMALS. AVAILABILITY IN LONG LENGTHS AND EASY HANDLING MADE BAMBOO A VERY USEFUL MATERIAL FOR BRIDGING CANNALS, DITCHES ETC. BAMBOO IS HOLLOW AND SO FLOATS ON WATER SO THE IDEA OF MAKING OF RAFT STRUCK WHEN THEY THOUGHT OF BETTER PROTEG TION FROM NATURAL CALAMITIES THE IDEA OF MAKING SHELTERS STRUK THEIR BRAINS. THUS THE POSTS & PURLINS CAME INTO THE PICTURE. SO BAMBOO TOGETHER WITH BRANCHES OF TREES FOUND A POSITION IN THOSE NOMADIC HUTS. ROOVES FOR THESE HUTS WERE HAYS, TREE LEAVES AND STRAW. ONE ADVANTAGE OF BAMBOOS OVER TIMBER WAS THAT THEY NEEDED SHAPING ONLY IN ONE DIMENSION BASICALY. THIS COULD BE DONE EASILY WITH STONE TOOLS WHICH OFCOURSE WAS HAMMERING AND BREAKING. BUT ON THE OTHERHAND TIMBER LOG WAS TO BE SHAPED FROM THREE DIMENSIONS WHICH MADE THOSE MEN TO USE ONLY THE HANDY BRANCHES OF TREES. AFTER-WARDS BAMBOO HOUSES ON TREE TOPS CAME TO THE PICTURE WHICH PROTECTED THEM FROM ANIMALS. FOR CLIMBING UP THE TREE THEY FOUND OUT THE SO CALLED LADDER.

YES, A REAL LADDER TO COME ONE STEP UP BOLDLY TOWARDS THE HUMAN CIVILIZATION OF TO-DAY! ▫ ▫ ▫ ▫ ▫

A SYSTEM OF BUILDING CONSTRUCTION WITH BAMBOO AS THE PRINCIPAL MATERIAL

DEVELOPMENT IN THE UTILITY PATTERN OF BAMBOO.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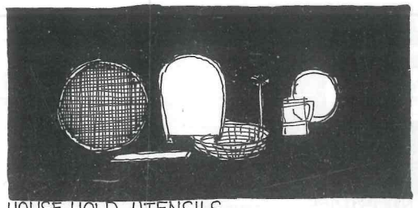
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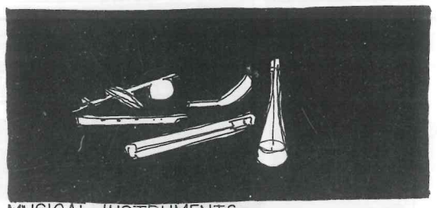
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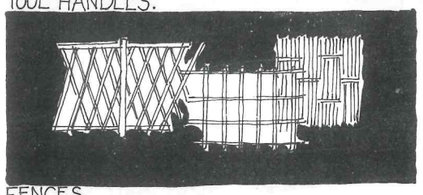
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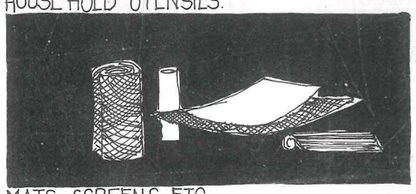
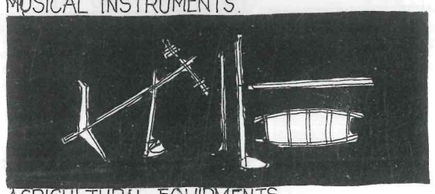

MATS, SCREENS ETC.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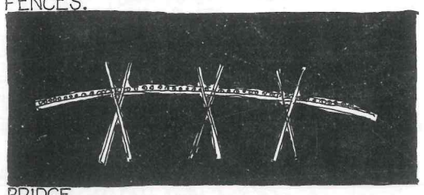
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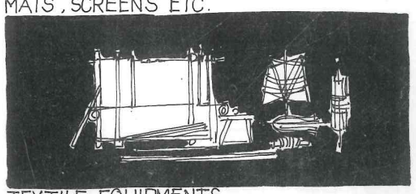
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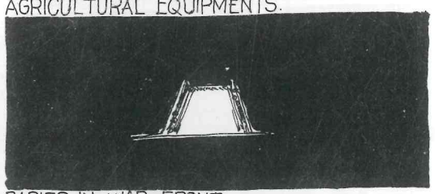
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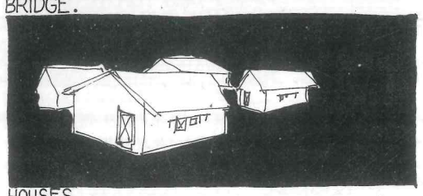
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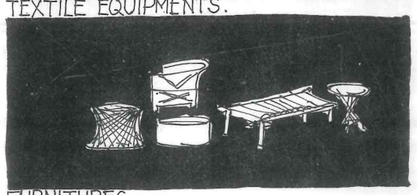
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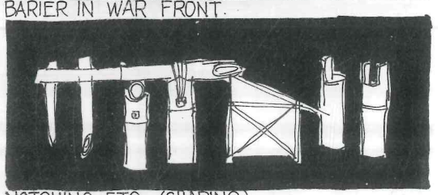
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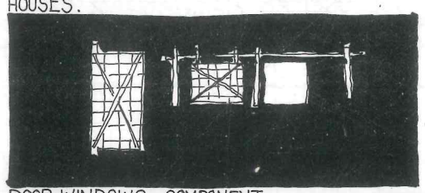
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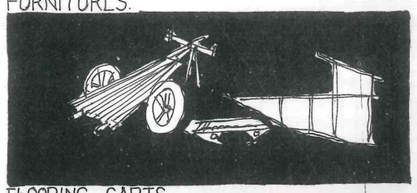
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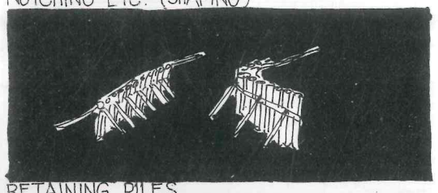
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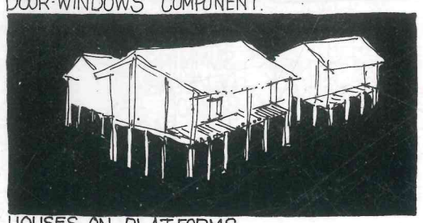
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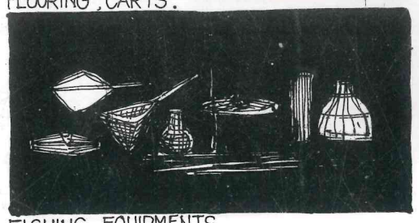
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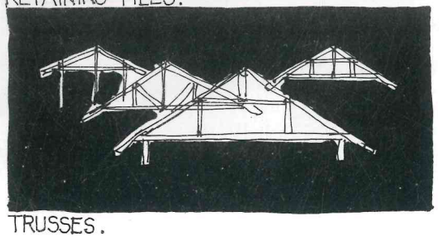
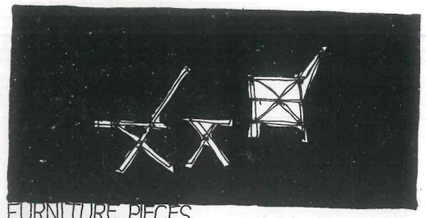

TRUSSES.

IN THE MEAN TIME.

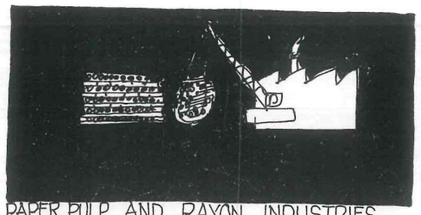
▫▫▫▫▫ THE IRON AGE GAVE BIRTH TO VARIOUS TYPES OF TOOLS FOR DIFFERENT MATERIALS WHICH HELPED MANKIND TO CONQUER THE MATERIAL WORLD. THUS **BAMBOO LIKE MANY OTHER MATERIALS STARTED TAKING SHAPES ON COMMAND OF MAN.** NOW, CUTTING, SPLITTING, RAMMING, TRIMMING ETC. BECAME EASIER. THENCE THE OLD CONSTRUCTION WAS REFINED AND EASY SHAPING OF BAMBOO CAUSED TO THE INVENTIONS OF MANY MORE NEW USES.

STARTING FROM THE SIMPLEST USES, THE TOOL HANDLE GOT A SHAPE TOGETHER WITH AN IRON RING TO ADD TO ITS STRENGTH. INCREASED UTILITY VALUED BAMBOOS MORE WHICH EXTINGUISHED THE BURNING OF BAMBOO AS FIRE WOOD. THE FENCES TOOK NEW TRIMMED SHAPE. THE BRIDGE BECAME NEW WITH CUT, SPITTED AND TRIMMED BAMBOOS. THE HOUSE BUILDING CHANGED TO A DEFINITE METHOD AND SHAPE. **REFLECTION OF THE USE OF TOOL BECAME VISIBLE** ON POSTS, PURLINS, RAFTERS ETC. DOORS-WINDOWS & ROOVES TOOK A TRIMMED SHAPE. ACCORDING TO NEED HOUSES ON PLATFORMS TOOK A SHAPE. EASY SPLITTING, FINENESS AND FLEXIBILITY CAUSED THE INTRODUCTION OF HOUSE HOLD UTENSILS LIKE SHIEVE, THRIVING BOARD, BASKETS ETC. TECHNIQUE OF WEAVING OF BAMBOO STRIPS SHAPED VARIOUS MATS. IN AGRICULTURAL FIELDS IT BECAME A VALUABLE ASSET. IN FISHING EQUIPMENTS BAMBOO SHOWED ITS BEAUTY AND FINENESS. BAMBOO OWING TO ITS SMOOTHNESS AND FINE GRAINS FOUND A POSITION IN DOMESTIC EQUIPMENTS FOR FABRICATION OF TEXTILES. LONG LASTING PERIOD AND HIGH STRENGTH-WEIGHT RATIO SHOWED THE WAY TO BE USED IN FURNITURE PIECES. WOVEN BAMBOO STRIPS MADE GOOD STRUCTURAL FLOORING FOR HOUSES, CARTS, BRIDGES & PLATFORMS. BAMBOO-PILES, FOR EASY DRIVING AND LOW COST, WERE USED FOR RETAINING EARTH. IN THE CREATION OF MUSICAL INSTRUMENTS ALSO BAMBOO BECAME COUNTABLE. IN WAR FRONTS ROWS OF BAMBOO-PILES TOGETHER WITH BAMBOO MATTING AND RETAINED EARTH BARRIERED ENYMIES. TRUSS WAS ANOTHER INTELLIGENT USE.

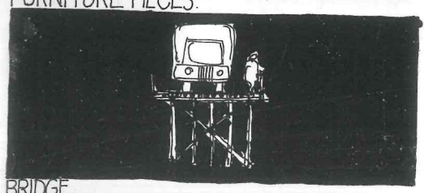
DEVELOPMENT IN THE UTILITY PATTERN OF BAMBOO.



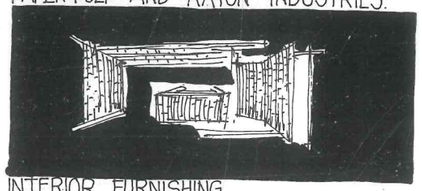
FURNITURE PIECES.



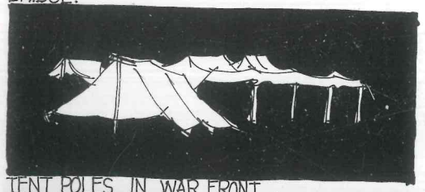
PAPER PULP AND RAYON INDUSTRIES.



BRIDGE.

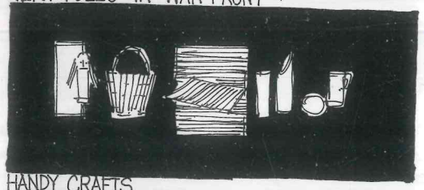


INTERIOR FURNISHING.

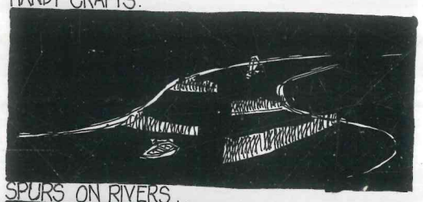


TENT POLES IN WAR FRONT

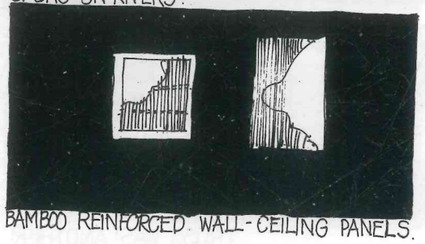
WHAT IS NEXT ?



HANDY CRAFTS.



SPURS ON RIVERS.



BAMBOO REINFORCED WALL-CEILING PANELS.

TO-DAY.

IN TO-DAYS' UTILITY PATTERN OF BAMBOO ONE WILL SEE - **A LITTLE MORE PONDER GIVEN TO THE MATERIAL**, A LITTLE MORE TOWARDS THE TECHNICAL SIDE. THE RESULT BEING - THE USE OF PRESERVATIVES USE OF MACHINES IN SMALL SCALE INDUSTRIES, USE OF HEAT IN BENDING BAMBOOS, USE OF FINISHING COAT OF CHEMICALS ETC.

THE FURNITURE PIECES OF TO-DAY HAVE A NEW LOOK, A BETTER FINISH WITH THE COAT OF A PRESERVATIVE. THE BAMBOO BRIDGES OF TO-DAY, DUE TO TECHNICAL USE CAN TAKE THE ROAD TRAFFIC - (A 5 TON TRUCK!). WOVEN BAMBOO MATS HAVE GOT A MORE TRIMMED SHAPE, BUT OWING TO LACK OF PRESERVATIVE TREATMENT IT WORNS OUT VERY SOON. STRONG VARIETY OF BAMBOO HAS FOUND A POSITION IN THE MASS PRODUCTION OF VARIOUS TYPES OF TENT POLES. MACHINE IS SHAPING IT IN THE SMALL SCALE INDUSTRY OF MAKING HOUSEHOLD UTENSILS, BAMBOO MATS, SCREENS, FURNITURE PIECES, DECORATIVE OBJECTS ETC. USE OF BAMBOO PILES IN SPURS FOR RETAINING THE RIVER BANK EARTH AND CHECK THE WATER CURRENT HAS BEEN POSSIBLE BECAUSE OF ITS LARGE AVAILABILITY AND LOW COST. IN TYPICAL CONSTRUCTION OF ASSAM TYPE HOUSE BAMBOO IS USED FOR REINFORCEMENT OF WALLS AND CEILING PANELS. BAMBOO USED INTERNALLY LASTS FOR A LONG PERIOD. SO IT HAS FOUND A POSITION IN INTERIOR FURNISHING OF BUILDING. ANOTHER LARGE-SCALE USE OF BAMBOO IS FOR PAPER-PULP AND RAYON INDUSTRY WHICH HOWEVER IS NOT ADVISIBLE FROM THE MATERIAL POINT OF VIEW. BAMBOO HAS GOT A STRUCTURE OF ITS OWN WITH ITS STRESS MORPHOLOGY. THEREFORE USE OF BAMBOOS FOR RAYON & PAPER-PULP INDUSTRIES IS NOTHING BUT TORTURING AND DESTRUCTING A STRUCTURAL MATERIAL. SUMMING UP IT CAN BE SAID THAT THE DEVELOPMENT IN THE UTILITY PATTERN OF BAMBOO HAS SLOWED DOWN. THE **FASCINATION TOWARDS MATERIALS** LIKE BRICK, R.C.C. ETC. HAS **CAUSED THE PARALYSIS** IN DEVELOPMENT OF UTILITY OF BAMBOO IN BUILDING CONSTRUCTION WHICH CAN STILL BE EXPLORED.

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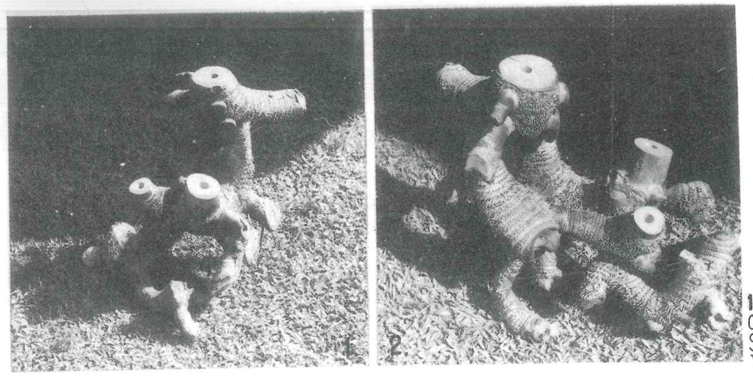
A SYSTEM OF BUILDING CONSTRUCTION WITH BAMBOO AS THE PRINCIPAL MATERIAL.

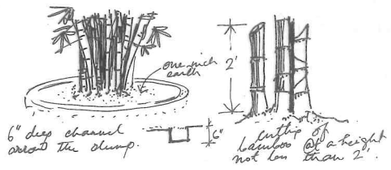
READING OF THE MATERIAL.

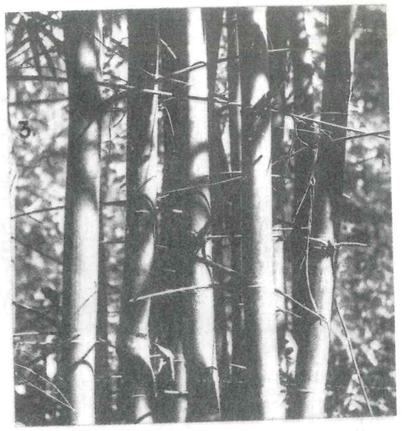


1&2. ROOT STRUCTURES OF BAMBOO, THE 'RHIZOMES' SHOWING MULTIPLE GROWTH.

FROM A FARMER'S EXPERIENCE.

AN EXPERIENCED FARMER RECOMMENDS A SIMPLE METHOD OF CARE TAKING FOR A BETTER GROWTH OF BAMBOO — A THIN LAYER OF ABOUT ONE INCH EARTH ON THE RHIZOMES TO GIVE MOISTURE AND PROTECT FROM DRY SUN, A DITCH OF NOT MORE THAN 6" DEPTH AROUND THE CLUMP AND CUTTING OF BAMBOO AT A HEIGHT OF NOT LESS THAN 2' TO PROTECT THE MOTHER CULM.



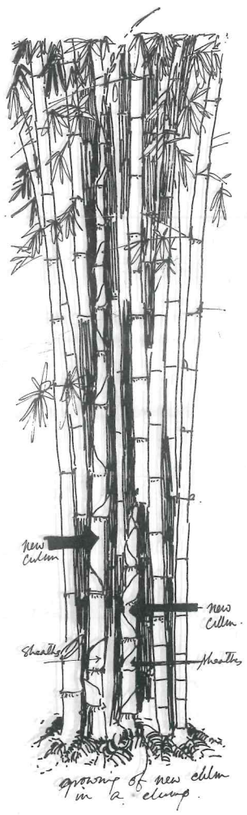


GROWTH OF BAMBOO.

BAMBOOS ARE PERENIAL GRASSES IN WHICH WOODY STEMS OR CULMS ARISE FROM THE WOODY ROOT-STRUCTURE CALLED **RHIZOMES.** CULMS APPEAR AT THE COMMENCEMENT OF THE PRINCIPAL RAINY SEASON IN THE FORM OF A POINTED CONE WHICH IS COVERED WITH OVERLAPPING SHEATHS INSERTED AT THE NODES. AS IT GROWS UP IN LENGTH, SHEATHS REMAIN STUCK UP AGAINST THE NODES AT REGULAR INTERVALS. A BAMBOO CULM ATTAINS ITS FULL HEIGHT AND GIRTH WITHIN **TWO TO FOUR MONTHS** AFTER IT SPROUTS OUT FROM THE MOTHER CULM, BUT IT TAKES **FULL ONE YEAR** TO ATTAIN SUFFICIENT STRENGTH FOR ITS FIBRES. WHEN THE BAMBOO MATURES FULLY, ITS SHEATHS FALL OFF AND SMALL TWIGS COME OUT FROM THE NODES. LIMBS OR BRANCHES DEVELOP ONLY AFTER THE UPWARD GROWTH OF BAMBOO CULMS IS COMPLETED. **TO ATTAIN FULL MATURITY A BAMBOO CULM REQUIRES TWO TO FOUR YEARS.** MATURITY CAN BE JUDGED FROM THE LOOK OF THE FIBRES WHICH ARE COMPACT AND WELLBUILT. A STROKE WITH THE FORE FINGER NAIL GIVES A RINGING SOUND. BAMBOOS GROW IN CLUMPS WHICH CONTAIN **50 TO 200** CULMS. INSPITE OF NOT TAKING SPECIAL CARE THEY ARE FOUND ABUNDANTLY IN NATURE.

GROWTH, NATURALLY, INCREASES IN A MULTIPLE WAY WHERE THERE IS SUFFICIENT CIRCUMSTANCES OF DEVELOPMENT OF GROWTH. COMMONLY, FROM ONE MOTHER CULM OR RHIZOME DEVELOP **TWO TO THREE** CULMS PER YEAR. THEREFORE FROM ONE MOTHER CULM NATURE OF PRODUCTION WOULD BE, AT THE END OF FIRST YEAR 3, AT THE END OF SECOND YEAR 3^3 BAMBOO CULMS AND SO ON. AT THE AVERAGE RATE, ONE CULM PRODUCES **30** CULMS IN 3 YEARS TIME.

SOMETIMES **EXTRA GROWTH** IS SEEN WHERE ROOTS COME OUT FROM LIMBS WHICH CAN BE PLANTED. BAMBOO CLUMP FLOWERS AFTER 40 TO 50 YEARS WHEN IT DIES AND NEW CULM COMES UP.



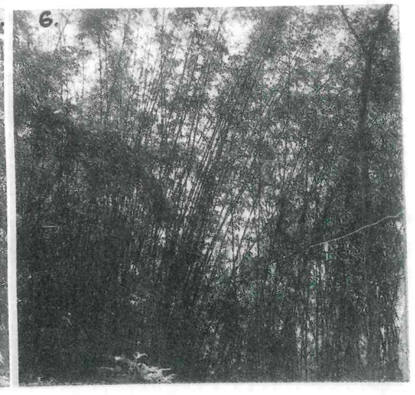
growing of new culm in a clump.

3. VIEWING CLOSELY, A CLUMP OF BAMBOOS COMMONLY AVAILABLE AFTER THE SHEATHS HAVE FALLEN OFF.

4. ANOTHER VARIETY OF COMMONLY USED BAMBOO. SOME OF THE CULMS HAVE NOT YET SHEDED THEIR SHEATHS.

5. GENERAL VIEW OF BAMBOO CLUMPS TOGETHER. IT SHOWS THE DENSITY OF CULMS OF A HEALTHY GROWTH.

6. FULL LENGTH VIEW OF BAMBOO CLUMPS. INDIVIDUAL CULMS ARE STRAIGHT BUT BEND SLIGHTLY BECAUSE OF ITS SELF WEIGHT AND GREAT LENGTH. A SLENDER MATERIAL OF NATURE.



READING OF THE MATERIAL.

SPECIES.

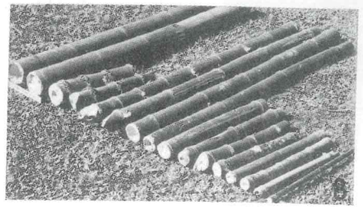
A GLANCE AT ALL INDIA SURVEY.

UPTO 1896, WHEN **GAMBLE** WROTE HIS MONUMENTAL TREATISE ON THE BAMBOOS (BAMBUSEAE) OF BRITISH INDIA, **115** SPECIES OF BAMBOO WERE RECORDED IN THE SEVEN PRINCIPAL REGIONS OF INDIA. THE POSITION UPTO 1958 (SO FAR AS PRESENT INDIA IS CONCERNED) IS THAT THERE ARE **136** SPECIES OF BAMBOO FOUND INDIA (RAIZADA & CHATTERJEE 1956) HOWEVER ONLY **30-40** SPECIES ARE CONSPICUOUS, EITHER IN THEIR EXTENSIVE OCCURENCE OR IN THEIR ECONOMIC EXPLOITATION. OUT OF THESE ONLY A FEW VARIETIES ARE USED FOR BUILDING CONSTRUCTION. FOLLOWING ARE THE **20** VARIETIES OF INDIAN BAMBOOS EXPLOITED FOR BUILDING CONSTRUCTION.*

LOCAL NAME	DISTRIBUTION
LILLI, BIJULI	**ASSAM**, NAGALAND.
KHNAP, USPAR	**ASSAM**, W. BENGAL.
CHEVANI	SOUTHERN & WESTERN INDIA.
KATA, KOTO, BIHER BANS, KOTOHA, DOWGA.	**THROUGHOUT INDIA.**
BALKA, BALUKA, BORUA, JHAIBARUA, SIL-BARUA,	**ASSAM**, BIHAR, W. BENGAL.
PICHLE, NAN BANS,	LOWER HIMALAYAS UPTO **ASSAM.**
BETUA, JAMA BETUA,	**ASSAM**, W. BENGAL.
JATI, TULDI,	**ASSAM**, W. BENGAL.
BANSI	**THROUGHOUT INDIA**
LATANG	**ASSAM**, BIHAR.
KOKWA, PECHA, MAKAL, KAKO, JAOWA, BAKAL.	**ASSAM**, W. BENGAL.
PECHA KOKWA.	**ASSAM**, W. HIMALAYAS.
WADAH, TIRIA.	**ASSAM**, SIKKIM.
MEDAR, SALIA, SAL,	**THROUGHOUT INDIA.**
MULI, TORAI.	W. BENGAL, **ASSAM.**
CHIVA	WEST COAST.
BOTANTGI BANS, WASHUT.	ORISSA, **ASSAM.**
BIJAL, TOLLI, NAL.	**ASSAM** & E. HIMALAYAS.
DULLOOWA.	**ASSAM.**
MARLONG.	**ASSAM.**

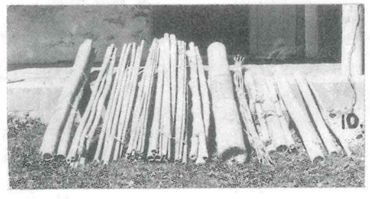
THEREFORE ALMOST ALL THE SPECIES OF INDIAN BAMBOOS ARE AVAILABLE IN THE PROVINCE OF ASSAM.

*(A HANDBOOK OF RURAL HOUSING AND VILLAGE PLANNING BY NATIONAL BUILDING ORGANISATION, NEW DELHI, INDIA.)



7,8 & 10 SHOW SIXTEEN MOST COMMON VARIETIES OF BAMBOO FOUND IN ASSAM.

9. ONE OF THE BHALUKA VARIETIES OF ASSAM. THE HUMAN HAND IN THE PHOTOGRAPH SHOWS THE SCALE OF THE DIAMETER OF THE BAMBOO. CIRCUMFERENCE IS FROM 18" TO 22".



BAMBOOS AVAILABLE IN ASSAM.

FOLLOWING ARE THE VARIETIES OF BAMBOO FOUND IN ASSAM WHICH DIFFER FROM ONE ANOTHER IN THEIR STRENGTH, WEIGHT, STRUCTURE AND SIZE.

JATI, BETUA. GREEN COLOUR, THIN BUT STRONG AND COMPACT FIBRES, INTERNODES 18" TO 24" LONG, CIRCUMFERENCE 8" TO 10", LENGTH 30 TO 40', SERVICEABLE LENGTH 25' TO 30', SKIN 9/16" TO 1/4" THICK, FAIRLY STRAIGHT. FIBRES VERY TENSILE; FINE AND STRONG, LATHS FOR PURPOSE OF TYING AND MAKING FINE STRIPS IS EASY. COMPRESSIVE STRENGTH IS FAIRLY HIGH; CAN RESIST VERTICAL HAMMERING FOR DRIVING, WITHOUT MUCH DAMAGE TO FIBRES. 'JAMA-BETUA' IS FOUND IN CACHAR; FIBRES VERY PLIABLE, MOSTLY USED FOR LATHS.

BAKAL, MAKAL. A VARIETY OF 'JATI.' COLOUR IS SLIGHTLY BLACKISH, INTERNODES ARE LONGER — 20" TO 28", GENERALLY VERY STRAIGHT, LONG AND STRAIGHT TWIGS COME OUT OF THE EYE OF THE NODE. FIBRES ARE HARD, THICK AND COMPACT, BUT NOT VERY PLIABLE, NO LATHS CAN BE SPLICED OUT, A THIN LATH EASILY BREAKS. COMPRESSIVE STRENGTH IS LESS THAN 'JATI'S. HAMMERING IN DRIVING SPOILS FIBRES FAIRLY QUICKLY.

KAKO, JAOWA, PECHA. SAME AS MAKAL IN APPEARANCE AND OTHER PARTICULARS, INTERNODES 10" TO 16", GIRTH 10" TO 12". A ROBUST KIND OF BAMBOO IN SIZE, SERVICEABLE LENGTH 30" TO 40", THICKNESS OF WALL 5/8" TO 1/4". FIBRES ARE LOOSE AND WEAK. TAKES LESS IMPACT LOAD, DRIVING SMASHES THE FIBRES AND SPLITS THE BAMBOO. ROTS EASILY, PRONE TO ATTACKS OF INSECTS.

BARUA, BHOLUKA. A VERY STURDILY BUILT ROBUST BAMBOO, THICK AND STIFF GRAINS, SHORT INTERNODES, THICK NODES, THICK SKIN, NARROW HOLLOW INSIDE; THICK NODES FROM WHICH FAIRLY LARGE AND LONG TWIGS COME OUT. TWIGS AND BRANCHES ARE SHARP AND A BIT PRICKY. GIRTH 12" TO 18"; INTERNODES 6" TO 15", SKIN 1" TO 1/2" THICK. SERVICEABLE LENGTH 30' TO 40'; NOT VERY STRAIGHT. TRANSVERSE STRENGTH IS MAXIMUM IN THIS VARIETY, CAN RESIST VERTICAL HAMMERING CONSIDERABLY, STRONGEST OF ALL THE VARIETIES.
'JHAIBARUA' OF CACHAR AND 'BHALUKA' ARE SAME. BARUA OF CACHAR IS STILL STRONGER.

READING OF THE MATERIAL.

SPECIES.

BAMBOOS AVAILABLE IN ASSAM.

SIL BARUA. IT GROWS IN CACHAR. VERY THICK SKINNED, PRACTICALLY SOLID, GIRTH IS 6" TO 8" INTERNODES 6" TO 10"; LENGTH 20' TO 25', SERVICEABLE LENGTH 16' TO 20'.

MULI, TORAI. VERY COMMON IN CACHAR AND LUSHAI HILLS, GIRTH AND LENGTH ARE BIG; ALSO IN GARO HILLS - WHERE IT IS KNOWN AS TORAI; THE GIRTH AND LENGTH ARE SMALL. A MEDIUM VARIETY GROWS IN THE KHASI HILLS. CACHAR VARIETY — GIRTH 6" TO 12", INTERNODES 12" TO 24", SKIN 3/8" TO 1/10". SERVICEABLE LENGTH 16' TO 20'. GARO HILL VARIETY - GIRTH 1½" TO 4", INTERNODES 20" TO 24", THICKNESS OF SKIN ½" TO 1/16". SERVICEABLE LENGTH 16' TO 18'.

DOLU. AN EVERGREEN SHRUBBY BAMBOO, GROWS IN HILLS; A VARIETY OF MULI, BUT SKIN IS THINNER, FIBRES ARE LOOSE AND WEAKER, INTERNODES ARE COMPARATIVELY LONGER - 1½' TO 3', GIRTH 1" TO 4½" SERVICEABLE LENGTH 16' TO 25'.

BIJLI. THIN, EVERGREEN, SHORT LENGTH, SHRUBBY BAMBOO, GROWS VERY THICK IN LARGE CLUSTERS. GIRTH 2" TO 4"; INTERNODES 12" TO 20". AVERAGE 16". LENGTH 16' TO 24'; SKIN 5/16" TO 3/16", FIBRES FAIRLY STIFF AND THICK.

MIRTINGA. A VARIETY OF BIJLI, GROWS IN CACHAR AND LUSHAI HILLS, THICK SKINNED, - WITH VERY LITTLE HOLLOW INSIDE, DIAMETER ½" TO ¾".

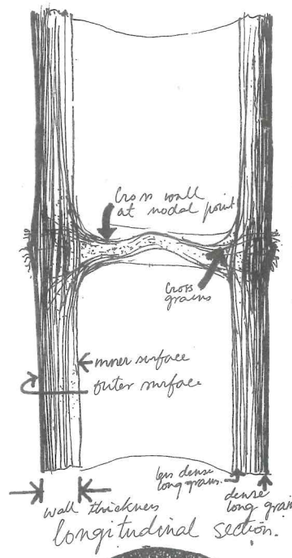
JILI. REALLY A REED-LIKE BAMBOO; DIAMETER ¼" TO ½"; LENGTH 6' TO 16', INTERNODES 6" TO 18", SKIN 1/8" TO 1/16". GROWS PROFUSELY IN SURROUNDINGS OF SHILLONG.

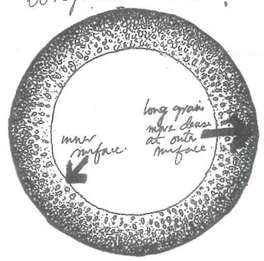
KATA, KOTOWHA. A THRONY VARIETY OF BHOLUKA THAT GROWS WILD MOSTLY IN SLOPES OF HILLS. ALL DETAILS ARE LIKE BHOLUKA OR BARUA, BUT, GIRTH, IS 4" TO 12", INTERNODES 9" TO 18". SERVICEABLE LENGTH 15' TO 25'. WALLS ARE VERY THICK ½" TO ¾", FIBRES ARE STURDY AND COMPACT; USUALLY NOT VERY STRAIGHT.

PHYSICAL STRUCTURE OF BAMBOO.

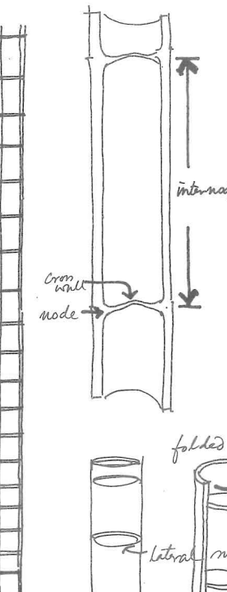
A BAMBOO IS COMPOSED OF : **LIGNIN** (THE MAIN WOODY SUBSTANCE) **STARCH, CELLULOISE, FAT** AND **WAX** FOR MAKING ITS MAIN BODY. **PECTOSE** IS THE COLOURING MATERIAL.

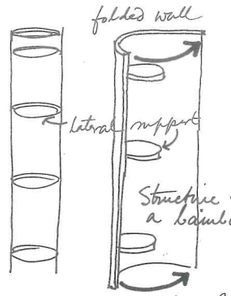
A BAMBOO IS **POROUS**. ITS PORES RUN VERTICALLY CLOSE, STRAIGHT, AND REGULAR SERIES TROUGH THE **SKIN OR WALL** OF BAMBOO ALONG THE LENGTH OF THE CULM. ITS **GRAINS ARE ALL STRAIGHT**, AND THAT IS WHY A BAMBOO CAN EASILY BE SPLITTED UP ALONG ITS LENGTH. IT IS **TENSILE**. ITS **NODES** ONLY HAVE **CROSS GRAINS**. THESE PORES FORM CAPILLARY TUBES THROUGHOUT THE LENGTH, WHICH IN THE GREEN STATE ARE FILLED WITH **SAP**, AND IN THE DRY STATE WITH AIR. THE INSIDE OF THE BAMBOO IS **HOLLOW** AND FILLED WITH AIR. THE LENTH OF THE **INTERNODES** AND HOLLOW SPACE INSIDE VARY IN DIFFERENT SPECIES OF BAMBOOS, AND ALSO FROM THE BOTTOM TO THE TOP IN THE SAME SPECIES. DUE TO THE HOLLOW SPACES IN THE INTERNODES AND THE AIR IN THE PORES OF THE SKIN, A BAMBOO **FLOATS ON WATER** BOTH IN THE GREEN AND THE DRY STATE.

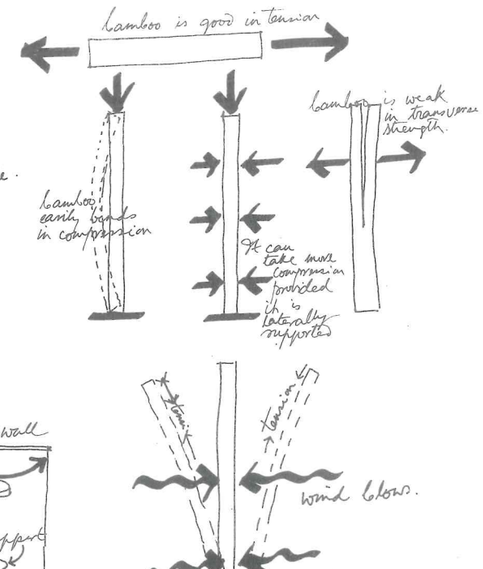


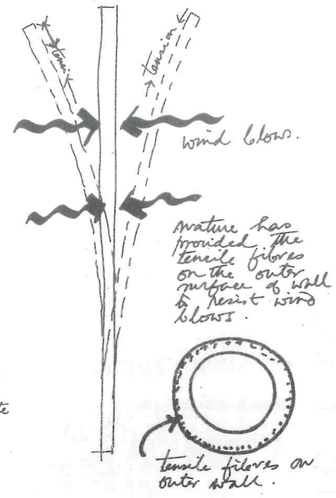


Cross Section of a bamboo









Bamboo floats in water due to hollow structure.

READING OF THE MATERIAL.
STRUCTURAL AND STRENGTH PROPERTIES.

STRENGTH PROPERTIES OF BAMBOO VARY ACCORDING TO THE MOISTURE CONTENT IN BAMBOO. WHEN MOISTURE IS LESS STRENGTH IS MORE. FOLLOWING ARE THE TECHNICAL DATA ON THE STRENGTH OF BAMBOO.

PERMISSIBLE **TENSILE** STRESS ALONG THE GRAIN — 158·19 Kg/cm² (2250 P.S.I.) TO 450 Kg/cm² (6294 P.S.I.)

TRANSVERSE STRESS — 49·3 Kg/cm² (686 P.S.I.) TO 70 Kg/cm² (970 P.S.I.)

COMPRESSION STRESS — AVE. 105·5 Kg/cm² (1500 P.S.I.)

CRUSHING STRESS — 436·3 Kg/cm² (6000 P.S.I.) - GREEN. 643·6 Kg/cm² (8850 P.S.I.) - KILN-DRY.

BOND STRESS — 5·6 Kg/cm² (80 P.S.I.) - SEASONED. 3·5 Kg/cm² (50 P.S.I.) - GREEN.

YOUNG'S MOD. — 175,750 Kg/cm² TO 196,860 Kg/cm². (2 TO 2·8 X 10⁶ P.S.I.)

MOD. OF RUPTURE. — 99·80 Kg/cm² (13,600 P.S.I.) GREEN. 1352·7 Kg/cm² (18,600 P.S.I.) KILN-DRY.

MOD. OF ELASTICITY. — 157 Kg/cm² (2,220 P.S.I.) GREEN. 186·5 Kg/cm² (2,560 P.S.I.) KILN-DRY.

TENSILE STRENGTH OF BAMBOO IS AN EXTREMELY VARIABLE QUANTITY (VARIES FROM 10,000 TO 50,000 P.S.I.) BUT DUE TO SHEAR THE CULM FAILS LONG BEBORE ITS FULL TENSILE STRESS IS DEVELOPED. STRENTH IS FROM **⅓ TO ⅛ OF STRENTH OF STEEL.** BAMBOO IS **2 TO 2·5 TIMES STRONGER THAN MASS CONCRETE IN COMPRESSION** (MASS CONCRETE — 40 TO 50 Kg/cm² OR 600 P.S.I). **BOND STRENGTH** OF BAMBOO IS **20% WEAKER** IN CASE OF SEASONED BAMBOO AND **50% WEAKER** IN CASE OF GREEN BAMBOO.

WEIGHT

A STACK OF WHOLE BAMBOOS WEIGHS (22 TO 25 lbs/cu.ft.) 81 TO 85 Kg/m³. AND THAT OF SPLIT BAMBOOS, AVERAGE ¾" WIDE SPLIT, WEIGHS (18 TO 20 lbs/cu.ft.) 75 TO 78 Kg/m³. WEIGHT OF SOLID BAMBOO IS 71·5 TO 735 Kg/ (15 TO 17 lbs/cu.ft.).

[WEIGHT OF BAMBOOS PER UNIT LENGTH, ARE — JATI, MAKAL, BETUA, BAKAL — 7·5 Kg/m (1lb/ft.); KAKO, JAOWA — 10·85 Kg/m (1·5 lbs/ft.); BHALUKA, BARUA — 14·6 Kg/m (2 lbs/ft.); MULI — ·2 TO ·5 Kg/m; DOLU, MIRTINGA — ·2 TO ·3 Kg/m.]

SHRINKAGE

SHRINKAGE IS DETERMINED FOR BOTH THE DIAMETER & THE WALL THICKNESS. IMMATURED BAMBOOS SHOW EXCESSIVE SHRINKAGE. SHRINKAGE OF ½ YEAR OLD BAMBOO IS FROM 11·6% IN DIAMETER AND 15·7% IN WALL THICKNESS FROM GREEN TO OVEN-DRY. SHRINKAGE IN LENGTH IS NEGLIGIBLE BEING ONLY 0·01%. BUT A FULLY MATURED BAMBOO PRACTICALLY DOES NOT SHRINK WHEN DRIED.

EFFECT OF DISPOSITION OF NODES IN BAMBOOS ON STRENGTH PROPERTIES.*

NODE IS THE THICKENING OF BAMBOO AT REGULAR INTERVALS ALONG ITS LENGTH. THE WALLS ARE THINNER ON BOTH SIDES OF THE NODE. THE CROSS WALL AT NODE SEPARATES THE (CAVITY) HOLLOW IN SEGMENTS. THE NODES AND THE CROSS WALLS SEEM TO HAVE BEEN INTRODUCED BY THE NATURE TO STIFFEN THE BAMBOO CULM TO PREVENT BUCKLING AND COLLAPSING. THE DISPOSITION OF THE NODES WAS, THEREFORE, EXPECTED TO EFFECT THE STRENGTH TO SOME EXTENT. IT HAS BEEN PROVED NOW THAT THE MAIN EFFECTS OF THE DISPOSITION OF NODES ARE SIGNIFICANT IN THE CASE OF STATIC BENDING BUT NOT SIGNIFICANT IN THE CASE OF MAXIMUM CRUSHING STRESS.

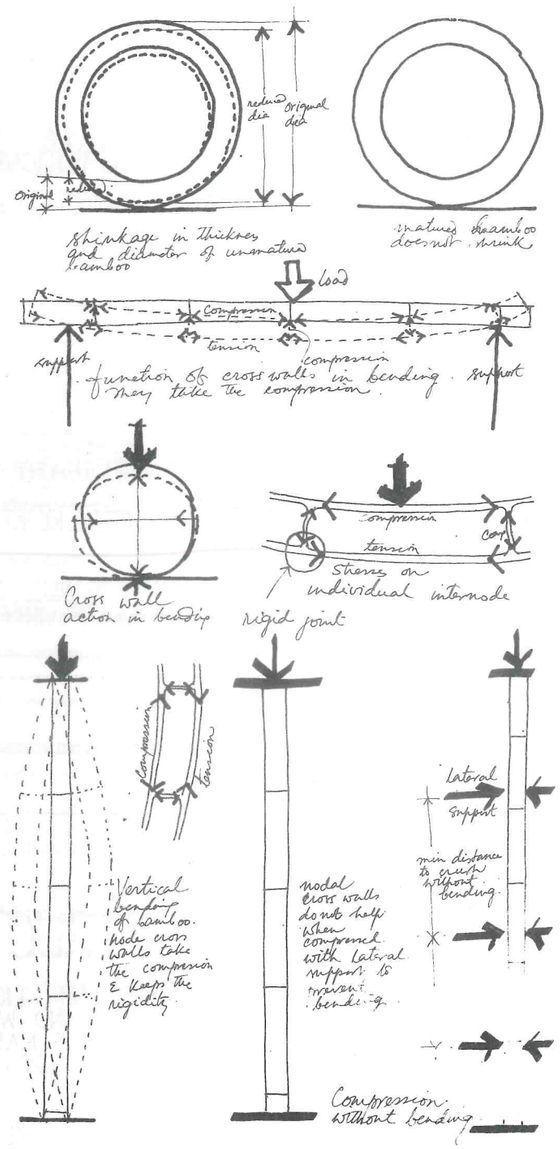
STRENGTH ALONG THE CULM.

THE BOTTOM PORTION IS SIGNIFICANTLY STRONGER IN MODULUS OF RUPTURE THAN BOTH THE TOP AND THE MIDDLE. THIS IS DUE TO THE GREATER WALL THICKNESS OF THE WALL TOWARDS THE BOTTOM. THERE IS PRACTICALLY VERY LITTLE DIFFERENCE OF COMPRESSIVE STRENGTH FOR THE THREE POSITIONS. MODULUS OF ELASTICITY IS, HOWEVER, SEEM TO HAVE A LOWER VALUE FOR THE BOTTOM PORTION.

EFFECT OF AGE ON STRENGTH

THE INCREMENT IN STRENGTH OF 2½ YEARS AGED OVER THAT OF ½ YEAR AGE IS 79% IN MODULUS OF RUPTURE, 38% IN MODULUS OF ELASTICITY AND 76% IN MAXIMUM CRUSHING STRESS. THE AVERAGE OF BAMBOO IN THE KILN DRY STATE SHOWS THE SAME GENERAL TREND AS IN THE GREEN CONDITION.

*[BASED ON EXPERIMENTS DONE BY MR. V.D. LIMAYE. F.R.I. DEHRADUN. INDIA.]



READING OF THE MATERIAL.

DEFORMATION OF BAMBOO.

DUE TO INSECTS. IMMATURED BAMBOO IF ATTACKED BY INSECTS GETS DEFORMED. DEFORMITY IS SEEN IN ITS GROWTH OF INTERNODES AND STRAIGHTNESS. THE NODES BECOME TOO CLOSER AND THE BAMBOO LOSES ITS STRAIGHTNESS. THESE, HOWEVER, ARE NOT VERY OFTEN SEEN.

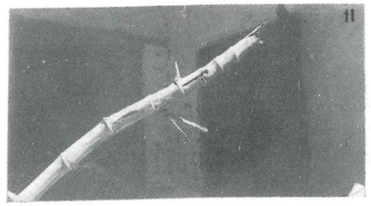
DUE TO INJURY. INJURY IN A SOFT YOUNG BAMBOO CAUSES DEFORMATION. THIS INJURY MAY BE DUE TO HAMMERING OR CUTTING OR CRACKING. RAINWATER COLLECTS THROUGH THE INJURY THEREBY INVITING VARIOUS INSECTS AND THE FIBRES ARE WEAKENED. THEREFORE IT LOSES STRENGTH AND BEAUTY. A LITTLE CARE WHILE CUTTING BAMBOOS FROM THE CLUMP MAY STOP THIS TYPE OF DEFORMATION.

DUE TO WIND STORM. INDIVIDUAL BAMBOO HAS GOT A POOR HOLDING IN THE GROUND TO HOLD ITSELF FIRM AND STAND ERRECT. BUT IN A CLUMP THEY ARE STRONG ENOUGH TO KEEP THEMSELVES ERECT. SO LESS DENSELY GROWN INDIVIDUAL BAMBOOS ARE SOMETIMES AFFECTED BY STRONG WIND FOR WHICH THEY GET BENT. IF A BAMBOO GETS BENT BEFORE ITS GROWTH HAS STOPPED THEN THE BAMBOO DEVELOPES IN THE BENT MANNER. NECESSARY SUPPORTS MAY PREVENT IT.

DUE TO THE DENSITY IN A CLUMP. IF A BAMBOO CLUMP GETS VERY DENSE DUE TO ITS UNUNIFORM CUTTING OR NOT PULLING DOWN THE MATURED BAMBOOS THEN THE SPROUTS MAKE THEIR OWN WAY THROUGH THE GAPS IN THE CLUMP FOR HAVING NO ROOM FOR THEIR NATURAL STRAIGHT GROWTH. THEREFORE THE STRAIGHTNESS IS LOST AND THE DISTRIBUTION OF NODES BECOMES UNUNIFORM. THIS IS OFTEN SEEN IN THE THORNY 'KOTOWHA' VARIETY. REGULAR AND UNIFORM CUTTING OF MATURED BAMBOOS MAY PREVENT BAMBOOS FROM THE PHENOMENON.

INSECTS.

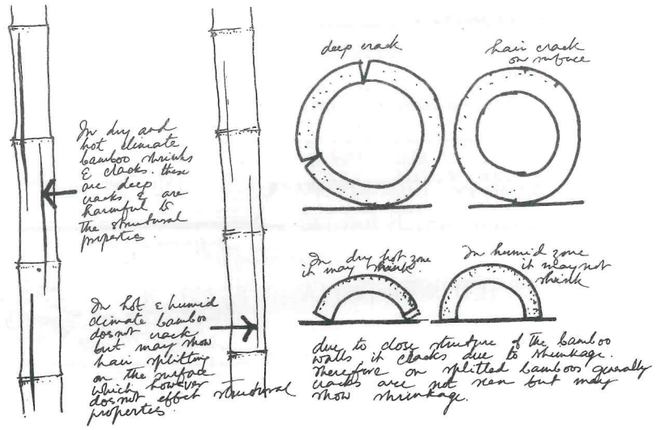
STARCH IS THE SOURCE OF WEAKNESS IN A BAMBOO. THIS SUBSTANCE ATTRACTS BAMBOO BEETLES OR 'GHOONS', A KIND OF CREATURES, WHICH ONCE IT GETS IN BREEDS IN THOUSANDS WITHIN A SHORT TIME AND EATS UP ALL THE STARCH LEAVING OUT ONLY THE SKIN & SOME WOODY SUBSTANCE. TERMITES OR WHITE ANTS ARE ALSO ATTRACTED BY BAMBOOS LIKE TIMBER. ALL THESE INSECTS, HOWEVER, CAN BE TAKEN CARE OF.



11. DEFORMATION DURING GROWTH DUE TO INSECT ATTACK.

12. DEFORMATION DUE TO DENSITY IN A CLUMP.

13. BAMBOO 'BEETLES' OR 'GHOON' ATTACK ON BAMBOO.



CRACKING OF BAMBOO

IN DRY AND HOT CLIMATE UNSEASONED BAMBOO TENDS TO CRACK ALONG ITS LENGTH WHICH HOWEVER DOES NOT LESSEN THE TENSILE STRENGTH. SEASONED BAMBOOS SHOW ONLY HAIR CRACKS. IN HOT AND HUMID CLIMATE BAMBOOS, PROPERLY MATURED, DO NOT CRACK BUT MAY SHOW HAIR CRACKS WHICH DOES NOT PRACTICALLY AFFECT THE STRENGTH PROPERTY. SEASONED OR PRESERVATIVE TREATED BAMBOOS NEVER CRACK IN HUMID AND HOT CLIMATE. THIN WALLED BAMBOO CRACKS EASILY THAN THOSE WITH THICK WALLS. THESE NTURAL CRACKS NEVER HAPPEN ACROSS THE LONG GRAINS OR FIBRES OF BAMBOO. HALF ROUND OR OTHER SPLITTED BAMBOOS DO NOT SHOW CRACKS AS THE CLOSED SHELL TYPE STRUCTURE IS BROKEN.

BAMBOO AVAILABILITY IN ASSAM.

ASSAM ABOUNDS IN FOREST RESOURCES. NEARLY **TWO FIFTHS** OF THE STATES TOTAL AREA IS COVERED WITH FORESTS. THESE FORESTS OF ASSAM CONTAIN THE **LARGEST RESERVE OF BAMBOOS IN INDIA.** THE TOTAL POTENTIAL BAMBOO SURPLUS IS ESTIMATED AT **1,406,400 AIR DRY TONS PER YEAR.*** THE BAMBOO RESOURCES OF ASSAM IS SO ENORMOUS THAT NO FORSEEABLE EXPANSION OF THE PULP AND PAPER INDUSTRY COULD CONSUME THE TOTAL AVAILABLE SUPPLIES OF BAMBOO.*

CUTTING SEASON.

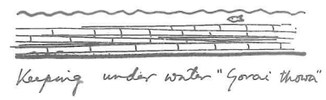
STARCH IS THE MAIN BODY BUILDING MATERIAL OF BAMBOO, AND IT IS IN ITS PEAK STATE FROM END OF JUNE TO END OF SEPTEMBER. ANY BAMBOO CUT DURING THIS SEASON HAS GOT A HIGH PERCENTAGE OF STARCH CONTENT IN THE FLUID STATE AND THE SKIN IS WEAK AND EASILY LIABLE TO ATTACKS OF BEETLES OR OTHER INSECTS. DURING THE PEAK SEASONS OF STARCH FORMATION, THE SPROUTS GROW UP FROM THE RHIZOMES AND IT IS REALLY A BREEDING SEASON. TO CUT A BAMBOO FROM A CLUMP AT THIS TIME MEANS HAMPERING OF GROWTH OF BAMBOO. SO BAMBOOS MAY BE CUT FROM **OCTOBER TILL MAY.** ONLY MATURED BAMBOOS ARE CUT CAREFULLY FROM THE CLUMP. ADEQUATE MATURED BAMBOOS ARE RETAINED TO SUPPORT THE IMMATURED BAMBOOS IN THE CLUMP.

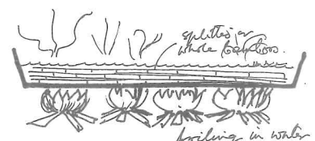
*TECHNO-ECONOMIC SURVEY OF ASSAM BY— NATIONAL COUNCIL OF APPLIED ECONOMIC RESEARCH. NEW DELHI.

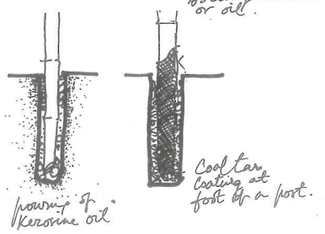
READING OF THE MATERIAL.
SEASONING AND PRESERVATIVE TREATMENT.

PRESENT PRACTICE.

A COMMON PRACTICE IS THAT GREEN BAMBOOS ARE **DIPPED IN MUDDY WATER** OF PADDY FIELDS TO WASH AWAY THE STARCH CONTENT OF BAMBOO. THIS IS LOCALLY KNOWN AS '**GORAI THOWA**'. THIS IS MORE PREFERABLE IN FLOWING WATER. IMMERSION FOR A PERIOD OF ONE WEEK IS ENOUGH. AFTER THAT BAMBOOS ARE DRIED UP IN A SHADED PLACE FOR ANOTHER WEEK.
A BETTER METHOD IS TO **BOIL A BAMBOO** OR A BAMBOO STRIP IN A BIG VESSEL OF WATER AT **100°F** (*ie.* JUST BOILING WATER) FOR 2½ HOURS AND THEN DRY IT UP IN SHADE. BAMBOO THUS TREATED LASTS FOR A LONG PERIOD, AND IF FURTHER **COATED WITH EARTH OIL, CREOSOTE OR SOLIGNUM**, ITS LIFE LASTS FOR NOT LESS THAN 40 YEARS WHICH IS THE LASTING PERIOD FOR A WELL SEASONED TIMBER. BOILING IN WATER AND THEN BOILING IN EARTH-OIL OR CREOSOTE FOR FURTHER 2 HOURS SHOWS STILL BETTER RESULTS.
ANOTHER CHEAPER PRACTICE IS TO **POUR KEROSINE OIL** INTO THE HOLE DUG FOR PUTTING A BAMBOO POST. A **COAT OF COAL TAR** AT THE FOOT OF THE BAMBOO POST KEEPS THE WHITE ANTS AWAY FROM IT.


Keeping under water "Gorai thowa"





NEW IMPROVED PRACTICE.

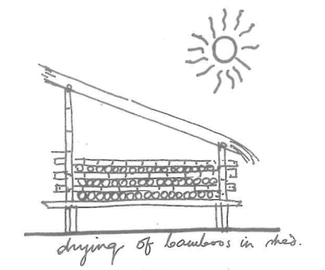
AIR SEASONING UNDER COVER FOR **2 TO 3 MONTHS** IS ADEQUATE NORMALLY. KILN SEASONING UNDER CONTROLLED CONDITIONS CAN BE CARRIED OUT SUCCESSFULLY IN 2 TO 3 WEEKS. BUT KILN SEASONING IS COSTLY. THE OUTER AND INNER MEMBRANES OF BAMBOO ARE QUITE REFRACTORY AND CAUSE SPLITTING UNDER QUICK DRYING. SO EITHER AIR SEASONING OR PROLONGED KILN SEASONING IS ADVISIBLE.

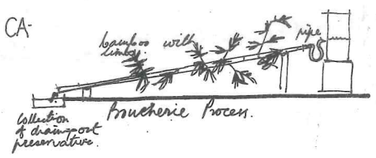
PREPARATION OF BAMBOOS FOR TREATMENT.

DEPENDING ON THE METHOD OF TREATMENT BAMBOOS ARE PREPARED FOR IT. FOR TREATMENT BY ORDINARY DIPPING METHOD THE BAMBOO IS CLEANED AND CUT INTO REQUIRED SIZES AND AT NODAL POINT HOLES ARE MADE.
FOR OTHER METHODS, THE BAMBOOS ALONG WITH THEIR BRANCHES & LEAVES ARE USED. THEY SHOULD BE FRESHLY CUT. IF, FOR SOME REASONS, IT IS NOT POSSIBLE TO TREAT THE BAMBOOS IMMEDIATELY AFTER THEIR CUTTING THEY SHOULD BE KEPT UNDER WATER FOR TWO OR THREE DAYS IMMEDIATELY AFTER CUTTING.

TREATMENT FOR BAMBOOS CAN GENERALLY BE DIVIDED INTO TWO CATEGORIES ——.

1. TREATMENT OF DRY BAMBOOS AND
2. TREATMENT OF GREEN BAMBOOS.


drying of bamboos in shed.



TREATMENT OF DRY BAMBOOS.

THESE MAY BE TREATED WITH A SOLUTION OF CREOSOTE AND FUEL (50:50) BY THE FOLLOWING THREE METHODS ——

HOT DIPPING (2 HOURS)	1-2 lbs./Cu.ft.
OPEN TANK (4-6 HOURS)	3-6 lbs./Cu.ft.
PRESSURE TREATMENT (1 HOUR.) PROCESS ...	3-8 lbs./Cu.ft.

THESE TREATMENTS CAN BE GIVEN BETTER IN CASE OF SPLIT BAMBOOS THAN ROUND ONES.

TREATMENT OF GREEN BAMBOOS.

DIFFUSION PROCESS. GREEN BAMBOOS ARE TREATED WITH WATER SOLUBLE PRESERVATIVES. THE BAMBOOS ARE SUBMERGED IN THE PRESERVATIVE SOLUTION FOR SUFFICIENTLY LONG TIME TO OBTAIN ADEQUATE ABSORPTION IN QUANTITY AND DEPTH. HOWEVER THE PROCESS, THOUGH EFFECTIVE AND ADEQUATE, TAKES 5 TO 6 WEEKS FOR THE TREATMENT.
ALTERNATIVELY, FRESHLY CUT BAMBOOS WITH LIMBS AND LEAVES ARE DIPPED IN THE SOLUTION. FROM THE TRANSPIRATION OF MOISTURE FROM THE LIMBS AND LEAVES, WHICH REMAIN IN AIR, THE PRESERVATIVE SOLUTION IS DRAWN UP INTO THE BAMBOO CULM. FOR TREATMENT IT NORMALLY TAKES ABOUT **2 DAYS**, WHICH DEPENDS ON THE LENGTH, SPECIE OF THE BAMBOO AND THE CLIMATIC CONDITIONS. FROM THE CHANGING COLOUR OF THE LEAVES, THE PROGRESS OF TREATMENT IS OBSERVED.

BOUCHERIE PROCESS. FRESHLY CUT BAMBOOS WITH LEAVES AND LIMBS ARE CONNECTED WITH TUBES TO DRUMS CONTAINING THE PRESERVATIVE SOLUTION. BAMBOOS ARE PLACED AT A SLIGHT INCLINED PLANE, KEEPING THE RESERVOIR AT A HIGHER LEVEL, SO THAT THE SOLUTION MAY FLOW ALONG THE BAMBOO. THE HIGHER THE RESERVOIR, THE QUICKER IS THE TREATMENT. SHORTLY AFTER ALLOWING THE SOLUTION TO FLOW, THE SAP STARTS FLOWING OUT OF THE LOWER END OF THE BAMBOO. THIS SHOULD BE ALLOWED TO FLOW OUT FOR A MINIMUM OF 20 MINUITES AND THE SOLUTION IS REJECTED. AFTER SOMETIME THE PRESERVATIVE SOLUTION COMES OUT SLOWLY FROM THE LOWER END. THIS IS COLLECTED AND REUSED.
IF AIR-TIGHT DRUMS FITTED WITH VALVE ETC. ARE USED AS A RESERVOIR OF SOLUTION, A SLIGHT PRESSURE CAN BE APPLIED WITH THE HELP OF A PUMP. IT INCREASES THE FLOW RATE AND MINIMISES THE TIME REQUIRED FOR TREATMENT. THE WHOLE ASSEMBLY IS SIMPLE AND INEXPENSIVE AND BY ITS USE THE TREATMENT MAY BE ACOMPLISHED WITHIN A FEW HOURS TIME.

READING OF THE MATERIAL.

SEASONING AND PRESERVATIVE TREATMENTS.

RECOMMENDED PRESERVATIVES AND TREATMENTS.

MODE OF USE OF BAMBOO.		PRESERVATIVES.	CONCENTRATION.	ABSORPTION.	TREATMENTS.
IN THE OPEN AND IN CONTACT WITH GROUND.	DRY-	a.	-	5 TO 8 lbs/Cuft.	OPEN TANK OR PRESSURE PROCESS.
		b AND c	6 TO 8%	5 TO 75 lbs/Cuft	PRESSURE PROCESS.
	GREEN-	b AND c	6 TO 8%	3 TO 8 lbs/Cuft.	MODIFIED BOUCHERIC FOR 6 TO 8 HOURS.
IN THE OPEN BUT NOT IN CONTACT WITH GROUND.	DRY -	a	-	3 TO 5 lbs/Cuft.	HOT DIPPING OR OPEN TANK.
		b AND c	5%	3 TO 5 lbs/Cuft.	PRESSURE PROCESS.
	GREEN	b AND c	5 TO 6%	3 TO 5 lbs/Cuft.	MODIFIED BOUCHERIC FOR 4 TO 6 HOURS.
WHEN USED UNDER COVER	DRY.	a.	-	2 TO 3 lbs/Cuft.	HOT DIPPING OR OPEN TANK.
		b AND c	4%	0·25 lbs./Cuft.	PRESSURE PROCESS.
		d, e AND f	6%	0·5 lbs/Cuft.	PRESSURE PROCESS.
	GREEN	b AND c	4%	0·25 lbs/Cuft.	MODIFIED BOUCHERIC FOR 4 HOURS.
		d, e AND f	6%	0·5 lbs/Cuft.	DIFFUSION FOR 15 TO 20 DAYS.
FOR FIRE RESISTIVE PURPOSES. (DRY, ROUND OR SPLITTED BAMBOO.)		K_1	15%	3 TO 5 lbs./Cuft.	PRESSURE PROCESS.
		K_2			APPLY ABOUT 1/8" TH. FILM *ie.* 4 TO 5 SQ.FT /lb.

FIRE RESISTIVE COMPOSITIONS.

K_1. AMMONIUM PHOSPHATE - 3 PARTS, BORIC ACID - 3 PARTS, COPPER SULPHATE - 1 PART, ZINC CHLORIDE - 5 PARTS BY WEIGHT IN 100 PARTS OF WATER. TO THIS A FEW DROPS OF CONCENTRATED HYDROCHLORIC ACID ARE ADDED WHICH IS JUST SUFFICIENT TO DISSOLVE THE THICK PRECIPITATE.

K_2. BOILER ASH - 25 PARTS, MICA POWDER - 25 PARTS, BORAX - 15 PARTS, ASBESTOS POWDER - 10 PARTS, ZINC OXIDE - 10 PARTS, TAMARIND SEED POWDER - 10 PARTS AND UREA FORMALDEHYDE GLUE - 24 PARTS BY WEIGHT. (SUITABLE CONSISTENCY FOR PAINTING)

PRESERVATIVES USED

a. COALTAR CREOSOTE AND FUEL OIL (50:50) BY WEIGHT. IN HIGHLY TERMITE INFECTED AREAS IT IS PREFERABLE TO ADD 1% DIELDRIN AND IN HIGHLY DECAYING AREAS 1% PENTACHLOROPHENOL.

b. COPPER-CHROME ARSENIC COMPOSITION (ASCU). A TYPICAL COMPOSITION OF THIS PRESERVATIVE COMPRISES OF COPPER SULPHATE, ARSENIC PENTOXIDE AND SODIUM OR POTASSIUM DICHROMATE IN THE PROPORTION 3:1:4.

c. ACID-CUPRIC-CHROMATE COMPOSITION (CELURE). IT COMPRISES OF 1·68 PARTS OF CHROMIC ACID (EQUIVALENT TO 2·5 PARTS OF SODIUM DICHROMATE) 50 PARTS OF COPPER SULPHATE, AND 47·5 PARTS OF SODIUM DICHROMATE.

d. COPPER-CHROME-BORIC COMPOSITION. THIS CONSISTS OF BORIC ACID, COPPER SULPHATE AND SODIUM OR POTASSIUM DICHROMATE IN THE PROPORTION OF 1.5:3:4.

e. COPPER-CHROME-ZINC-ARSENIC COMPOSITION. THIS COMPRISES OF 28 PARTS OF ARSENIC ACID, 25 PARTS OF SODIUM ARSENATE, 17 PARTS OF SODIUM DICHROMATE AND 30 PARTS OF ZINC SULPHATE.

f. CHROMATED ZINC CHLORIDE. THIS CONSISTS OF ZINC CHLORIDE AND SODIUM OR POTASSIUM DICHROMATE IN THE RATIO 1:1.

PROPHYLACTIC TREATMENT.

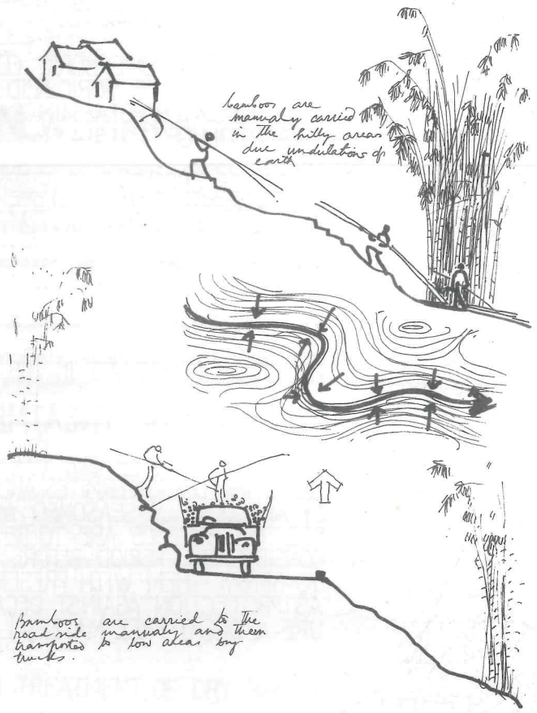
BAMBOOS ARE SUSCEPTIBLE TO QUICK ATTACK BY INSECTS INCLUDING TERMITES AND FUNGI UNLESS THEY ARE QUICKLY SEASONED AND PRESERVED. WHERE THE BAMBOOS ARE TO BE STORED FOR A CONSIDERABLE PERIOD BEFORE USE IT IS BETTER TO SPRAY THEM WITH PRESERVATIVE SOLUTION AS PROTECTION AGAINST DECAY. THIS WILL ENSURE A DECAY FREE MATERIAL FOR FUTURE USE.

READING OF THE MATERIAL.

MODES OF TRANSPORTATION.

IN THE HILLY AREAS.

DUE TO STEEP SLOPES AND NOT BEING ACCESSIBLE FOR AUTOMOBILES BAMBOOS ARE CARRIED MANUALLY FROM HILL SIDE JUNGLES BY THE HILL DWELLERS TO THE SITE OF CONSTRUCTION. ANOTHER MODE OF TRANSPORTATION, FOR LONG DISTANCE, IS THAT BAMBOOS ARE STACKED ON THE ROADSIDE AND THEN CARRIED AWAY BY TRUCKS. MIZO HILL IN ASSAM HAS A GREAT BAMBOO RESERVE WHICH DUE TO LACK OF PROPER TRANSPORTATION HAS NOT BEEN EXPLOITED IN STRUCTURAL WORKS.
BAD TRANSPORTATION HAS CAUSED THE BAMBOOS OF HILLS TO REMAIN UNSEEN.



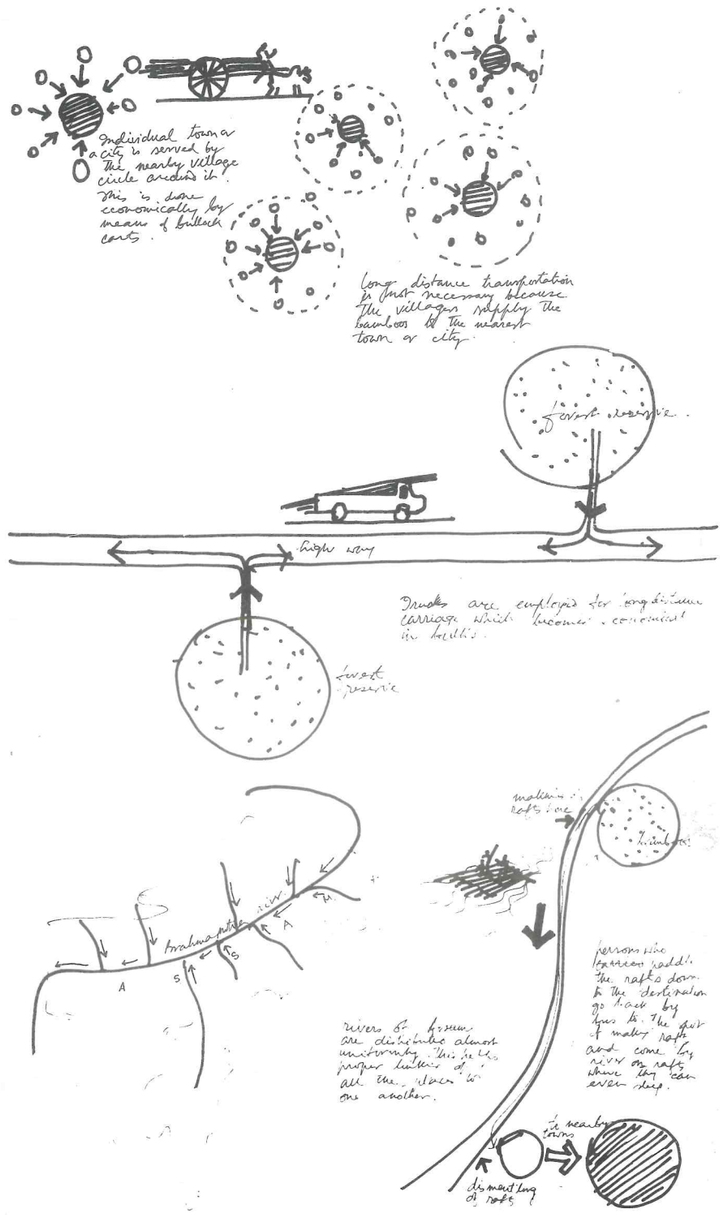
IN THE PLAIN AREAS.

THE GENERAL MODE OF SMALL SCALE TRANSPORTATION OF BAMBOO IS BY CARTS WHERE TRUCK CARRIAGE BECOMES UNECONOMICAL. BAMBOOS ARE SUPPLIED TO THE TOWNS FROM THE VILLAGE CIRCLE AROUND. THEREFORE LONG DISTANCE TRANSPORTATION IS NOT VERY NECESSARY UNLESS THERE IS AN INDUSTRY.

FOR LARGE SCALE TRANSPORTATION TRUCKS ARE EMPLOYED WHICH CARRY BAMBOOS FROM THE FOREST RESERVE BY ROADWAYS. ONE TRUCK CAN CARRY 100 TO 150 CULMS OF AVERAGE VARIETY TO 1500 CULMS OF SMALLER VARIETY.

ANOTHER MODE OF TRANSPORTATION, A MORE NATURAL WAY, IS RIVER TRANSPORTATION. RAFTS ARE MADE OUT OF BAMBOOS AND PADDLED DOWN THE RIVER TO THE DESTINED PLACES FOR DISTRIBUTION. RAFTS ARE DISMANTLED AND STACKED ON THE RIVERBANK. AND THEN SUPPLIED TO THE NEAREST TOWN. THIS TYPE OF TRANSPORTATION HELPS SEASONING OF BAMBOOS AS THE SAP AND STARCH CONTENT OF GREEN BAMBOOS GET WASHED AWAY.

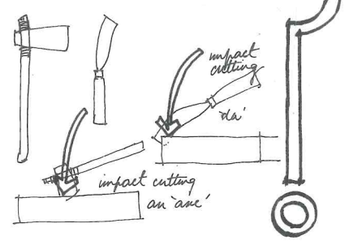
14. RIVER TRANSPORTATION OF BAMBOO.

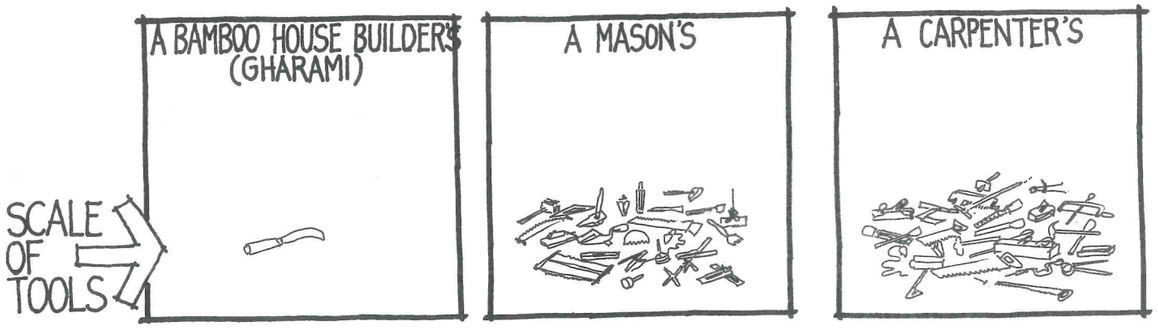


READING OF THE MATERIAL.
OBSERVATION : THE RESPONSIBLE TOOL THAT SHAPES THE MATERIAL.

HOW COULD A NOMADIC TOOL ALONE SHAPE A HOUSE OF TO-DAY

THE TOOL IS A 'DA' OR 'DAO' THE OPERATION OF WHICH IS LIKE THAT OF AN 'AXE' THE NOMADIC. ONLY THE SHAPE HAS UNDERGONE REFORMATIONS TO BECOME A 'DA' OR 'DAO' BASIC OPERATION REMAINING SAME. — THE 'IMPACT CUTTING AND' FORCED SPLITTING.





BASIC SHAPING.

TOOL IS A 'DA' OR 'DAO' ⇨ 15

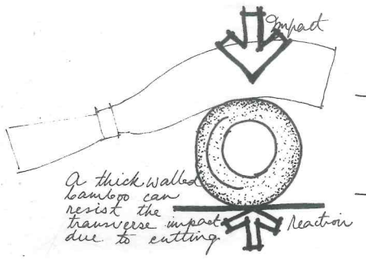
CUTTING.

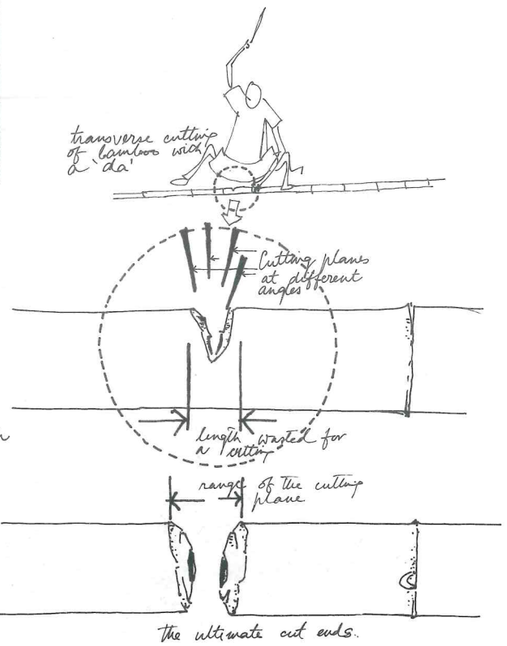
THICK WALLED BAMBOO.

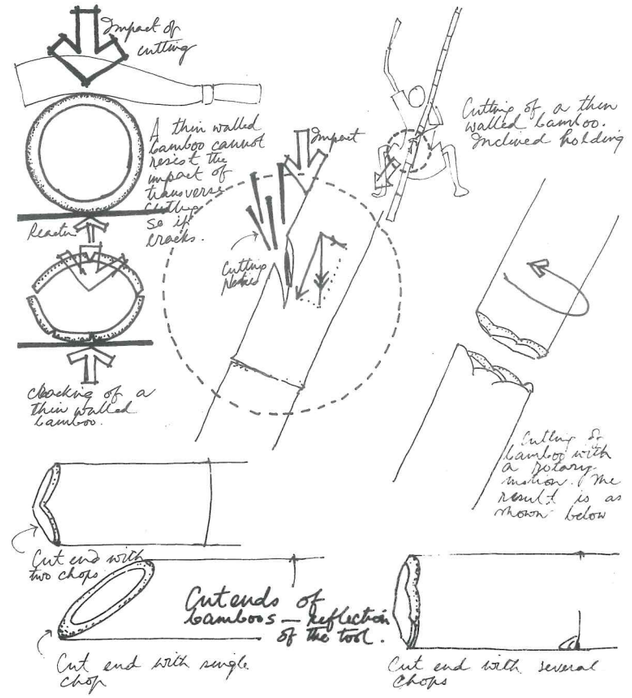
A THICK WALLED BAMBOO CAN RESIST THE TRANSVERSE IMPACT OF CUTTING. BUT DUE TO IMPOSSIBILITY OF PIN POINT HITTING THE ULTIMATE CUT END IS AN UNEVEN PLANE.

THIN WALLED BAMBOO.

A THIN WALLED BAMBOO CANNOT TAKE THE TRANSVERSE IMPACT OF CUTTING SO THEY ARE HOLD IN AN INCLINATION SO THAT THE IMPACT GOES ALONG THE GRAINS. THE RESULTS ARE SHOWN IN THE SKETCHES.





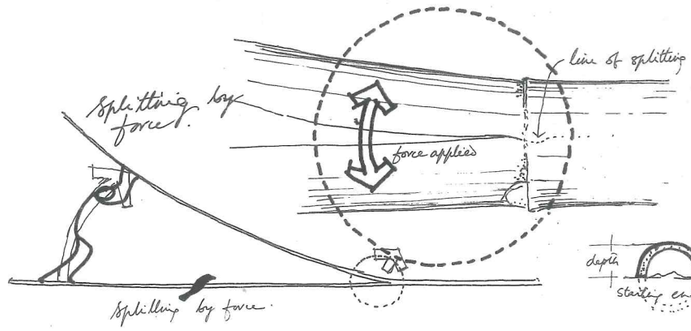


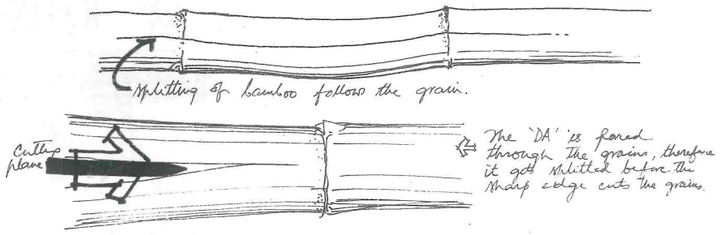
READING OF THE MATERIAL.
OBSERVATION : THE RESPONSIBLE TOOL THAT SHAPES THE MATERIAL.

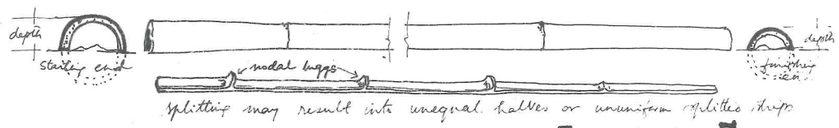
BASIC SHAPING.

SPLITTING.

IN THIS OPERATION THE 'DAO' IS FORCED THROUGH THE GRAINS OF BAMBOO. THE SPLITTING TAKES PLACE ALONG THE GRAINS. THEREFORE TWO HALVES OF A BAMBOO MAY OR MAY NOT BE EQUAL. IF THERE IS A BEND IN THE BAMBOO THEN SPLITTING ALSO BENDS ALONG IT. BY SPLITTING, A UNIFORM SECTION IS NEVER SURE. SPLITTING BY FORCE, AND NOT CUTTING, IS A MERE TORTURE TO THE MATERIAL.

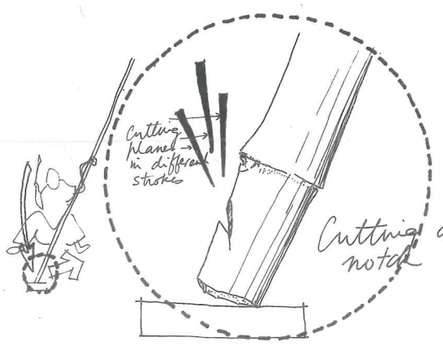


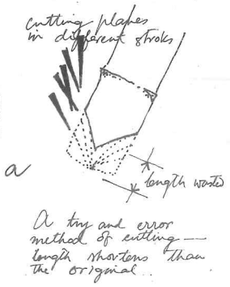


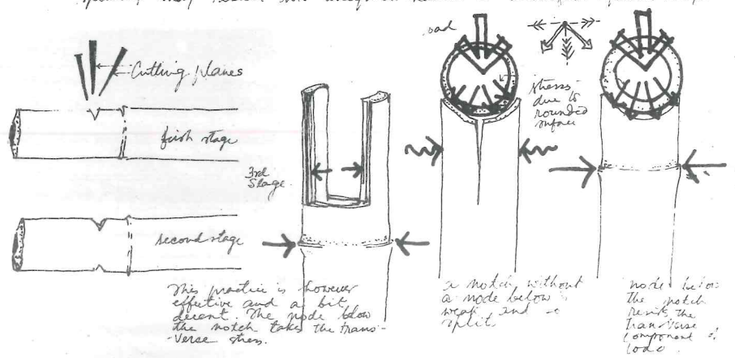


NOTCHING.

THIS OPERATION IS SOME WHAT A SUCCESS. BUT IT IS THE FORM OF THE BAMBOO THAT MAKES IT AND NOT THE TOOL. BECAUSE IMPACT CUTTING IS AGAIN NEVER SURE OF PIN POINT HITTING.
THIS IS EFFECTIVE WHEN THERE IS A NODE IMMEDIATELY BELOW THE NOTCH.

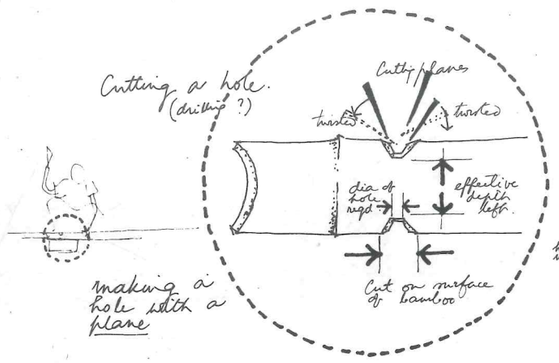


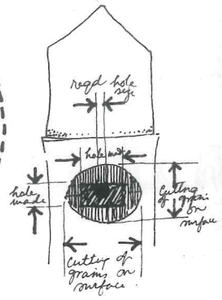


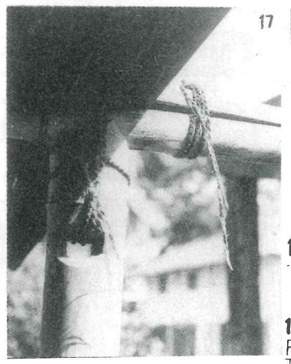


MAKING A HOLE.

'DAO' IS NEVER SUITED FOR MAKING A HOLE IN BAMBOO. A PLANE IS NOT SUITABLE FOR MAKING A HOLE BUT DUE TO THE FORM OF BAMBOOS A HOLE MAY BE CUT WHICH WEAKENS THE BAMBOO CONSIDERABLY.







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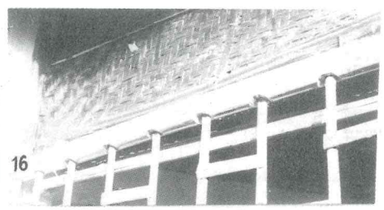


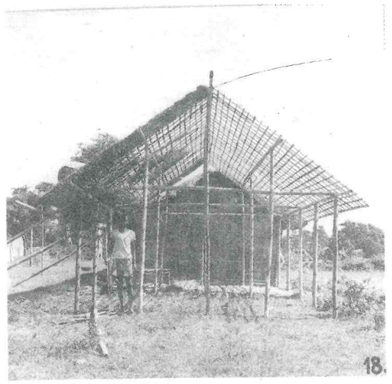
16

16. REFLECTION OF THE TOOL IN CONSTRUCTION NOTE THE HOLES MADE TO RECIEVE THE VERTICAL STUDS

17. A HOLE MUCH MORE BIGGER THAN THE REQUIRED. AN WASTAGE AND WEAKENING OF THE MATERIAL

A SYSTEM OF BUILDING CONSTRUCTION WITH BAMBOO AS THE PRINCIPAL MATERIAL.

READING OF THE MATERIAL.
OBSERVATION : A BAMBOO HUT WITH THATCHED ROOF.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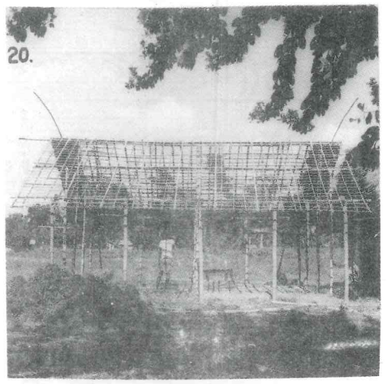
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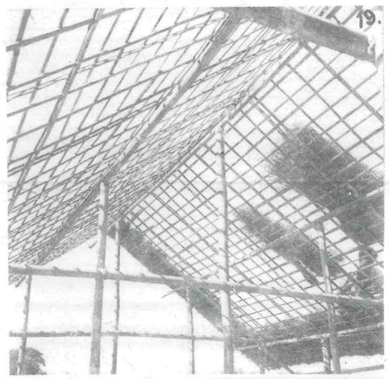
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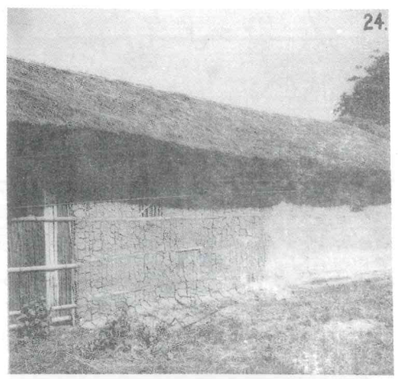
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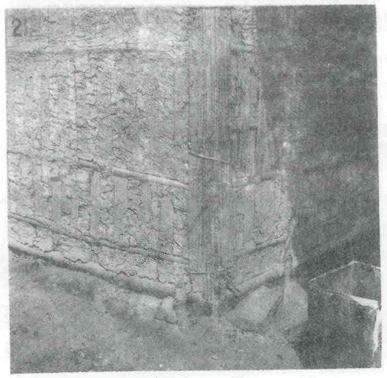
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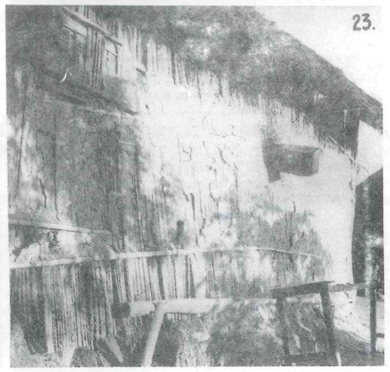
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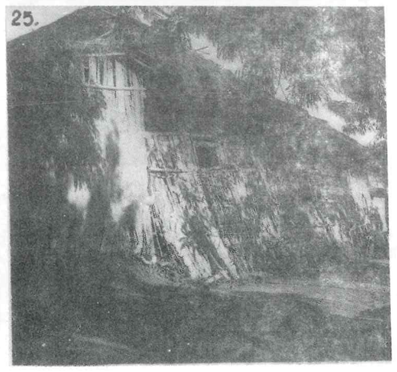

25.

DESCRIPTION

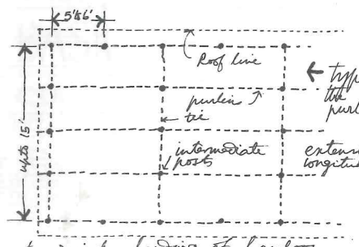
LOCATION — ASSAM.

THE MOST ECONOMICAL RURAL HOUSE OF ITS KIND. EASY AVAILABILITY OF BAMBOOS AND THATCH MAKES IT CHEAPER. PLANNING IS CONFINED TO RECTENGULAR SHAPE BECAUSE OF LIMITATION OF THE CONSTRUCTION SYSTEM. TOO MANY SUPPORTS TO THE ROOF DISTURBS THE SPACE INSIDE.

POSTS —— BAMBOO.
ROOF STRUCTURE —— BAMBOO.
ROOFING MATERIAL —— THATCH.
FLOOR —— EARTHEN, MUD PLASTERED.
PLINTH —— EARTHEN, WITH MUD PLASTER AND BAMBOO SUPPORTS FROM SIDE.
DOORS —— BAMBOO.
WINDOWS —— BAMBOO.
WALL —— BAMBOO REINFORCED MUD WALL.
HEIGHT —— GROUND FLOOR STRUCTURE.
FOUNDATION —— POSTS SIMPLY PUT INTO GROUND UPTO A DEPTH OF 2½' AND RAMMED.
COST —— RS. 2 PER SQ FOOT AREA OF FLOOR.
LIFE —— 15 TO 20 YEARS WITH CHANGING OF THE BAMBOO POSTS AT INTERVALS.

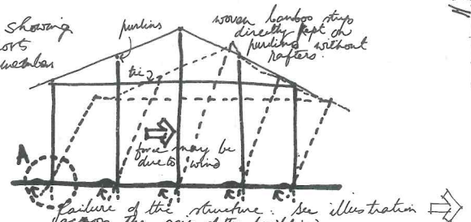
18. HUT IN THE CONSTRUCTION STAGE. FOUNDATION IS SIMPLY PUTTING OF BAMBOO INTO THE GROUND.
19. VIEW OF THE ROOF AND ITS SUPPORT FROM BELOW. SIMPLE POST AND PURLIN CONSTRUCTION. NOTE THE JOINTS.
20. VIEW OF THE HUT IN CONSTRUCTION STAGE FROM SIDE. NOTE THE LIGHTNESS OF THE ROOF STRUCTURE.
21. FAILURE OF THE PLINTH. WALL LOSES THE SUPPORT AND ULTIMATELY FAILS.
22. VIEW OF THE MUD PLASTERED WALL. THE FIRST COAT OF MUD.
23. CONSTRUCTION FAILURE OF WALL. SECURING OF WALL TO THE POSTS IS NOT PROPER.
24. VIEW OF THE WALL SHOWING THE STAGES OF PLASTERING.
25. THE COMMON FAILURE OF THE WALL. WASHING OF PLINTH.

READING OF THE MATERIAL.
OBSERVATION : A BAMBOO HUT WITH THATCHED ROOF.

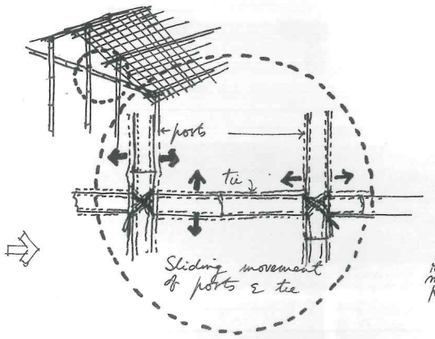


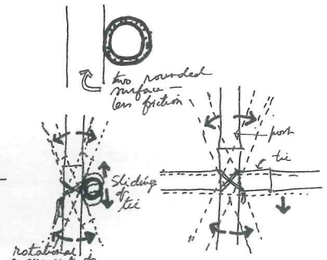
← typical plan showing the positions of posts purlins and tie members

to resist bending of bamboos support members are close. Therefore it obstruct the movement under the roof.

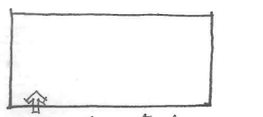


Failure of the structure (across the axis of the building) See illustration ⇨

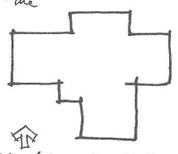




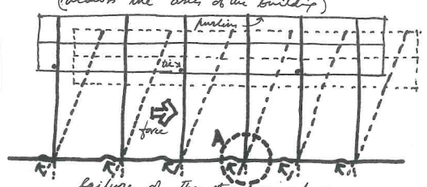
Tying of the different members is flexible and loose. If a simple tying joint, only rotation about the hinge is seen but in this case sliding is also possible because two rounded surfaces are just kept together with loose knot.



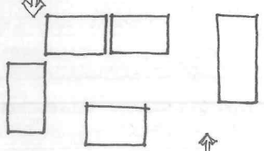
System of construction restricts the shape of the house to a rectangle



This type of shape with offsets are not possible in this type of construction.

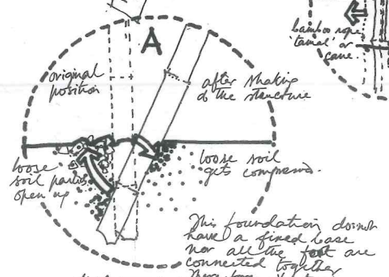


failure of the structure along the axis.

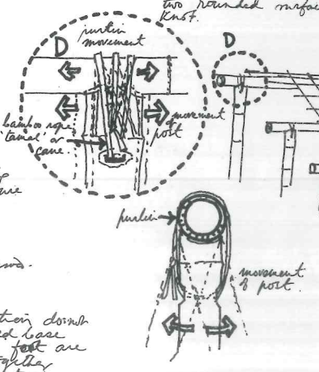


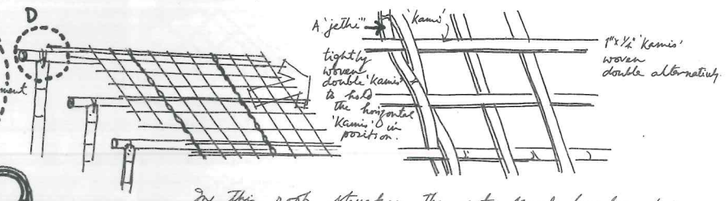
Therefore the cluster of houses are seen with a definite pattern in laying out.

a cluster is characterised by the individual structure for a family.

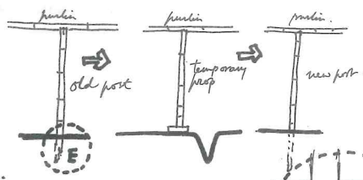


This foundation doesn't have a fixed base near all the feet are connected together. Therefore it topples.

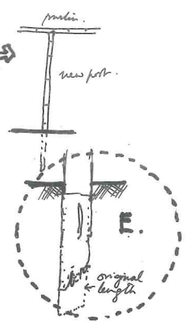


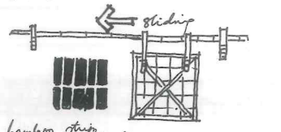


In this roof structure the network of bamboo strips (kamis) are directly kept on the purlins to receive the thatch on it. There are no rafters.



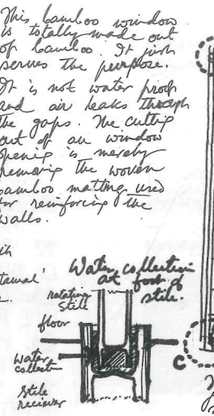
changing of post

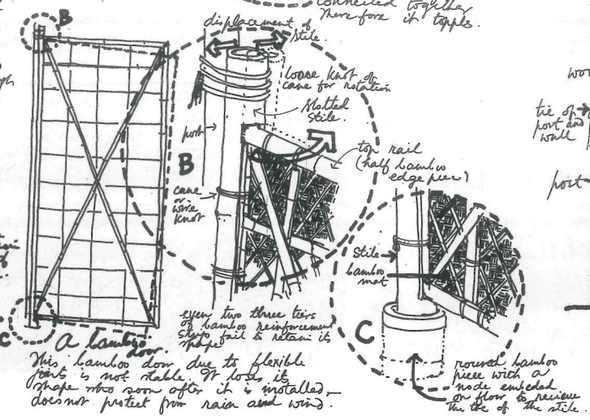




A bamboo window.

This bamboo window is totally made out of bamboo. It both serves the purpose. It is not water proof and air leaks through the gaps. The cutting out of an window opening is merely removing the woven bamboo matting used for reinforcing the walls.

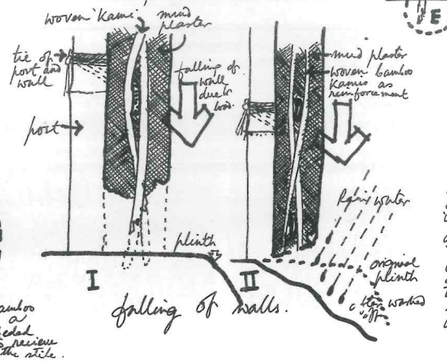




A bamboo door.

This bamboo door due to flexible joint is not stable. It looses its shape soon after it is installed. does not protect from rain and wind.

even two three tiers of bamboo reinforcement cages fail to retain its shape.

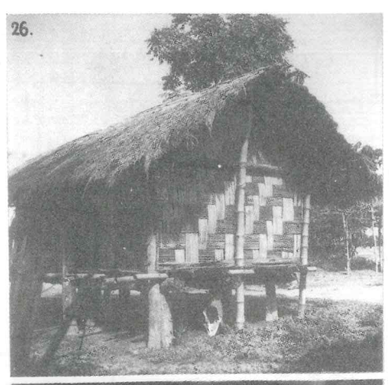


falling of walls.

In case no I — The bamboo reinforcement is eaten away by insects or dark rots due to dampness. In case II — the plinth is washed off by rain water. In both the cases when the support at the bottom of wall is missing. The wall hangs on the knots (tie with post) only which collapses. and the wall eventually

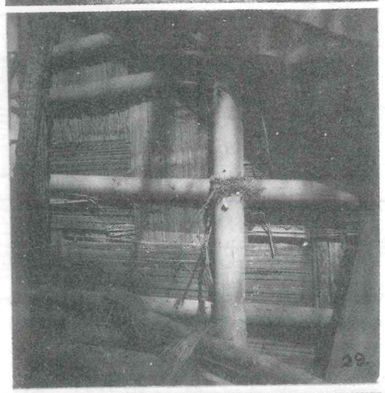
READING OF THE MATERIAL.

OBSERVATION : HOUSE ON A PLATFORM (MIRI SAANG-GHAR).


26.


27.


28.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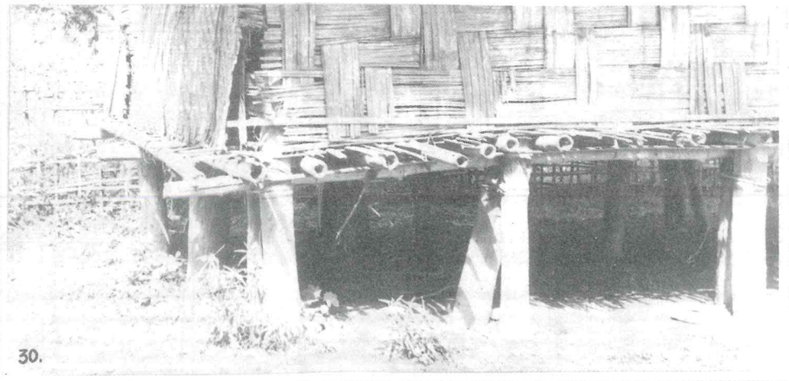
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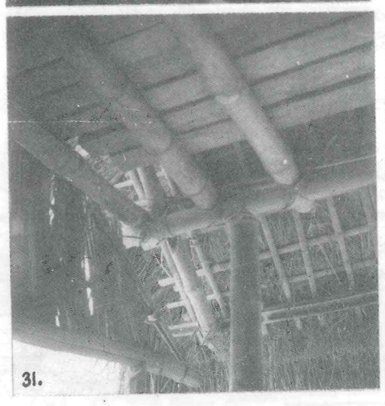
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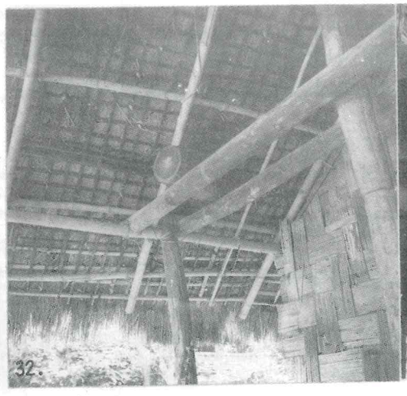
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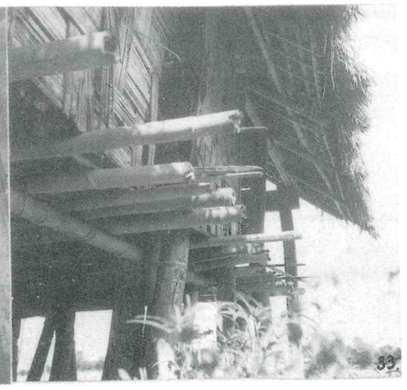
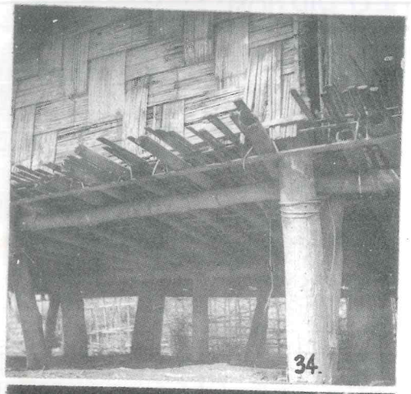

33.

DESCRIPTION.

LOCATION
ORIGINALLY THIS HOUSE WAS DONE, TO KEEP AWAY FLOOD, WATER, ON THE RIVER BANKS OR LOW LAND BY THE 'MIRIS' (TRIBAL PEOPLE) POOR ECONOMICAL CONDITION IS REFLECTED ON THE HOUSE. "DO WE THINK FOR THE BREAD OR THE HOUSE ? WHO CARES FOR DECENCY WHEN IT LASTS FOR 12 YEARS WITHOUT MUCH CARE ?"
POSTS — UNDRESSED TIMBER AND BAMBOO.
ROOF STRUCTURE — BAMBOO.
ROOFING MATERIAL — THATCH.
FLOOR — BAMBOO.
PLINTH — BAMBOO PLATFORM ON BAMBOO OR TIMBER POSTS.
DOOR — BAMBOO
WINDOW — NIL.
WALL — WOVEN BAMBOO.
HEIGHT — GROUND FLOOR STRUCTURE.
FOUNDATION — POSTS SIMPLY PUT TO 3' DEPTH INTO GROUND AND RAMMED FROM SIDES.
COST — RS. 2'40 PER SQ. FOOT OF FLOOR AREA.
LIFE — 12 TO 15 YEARS WITHOUT MAINTENENCE.

26. GENERAL VIEW OF THE MIRI-SAANG GHAR. NOTE THE WALL PANEL SIZE.
27. END VIEW OF TH HOUSE. NOTE ROOF OVERHANG.
28, 29, 31, 32, 33. CARELESS AND IMMATURE CONSTRUCTION. NO SYMPATHY TOWARDS THE MATERIAL.
30 LOSS OF PLUMB, LOSS OF LEVEL. NOTE JUNCTIONS OF WALL AND SPACING OF FLOORING MEMBERS.

READING OF THE MATERIAL.
OBSERVATION : A HOUSE ON A PLATFORM (MIRI SAANG-GHAR).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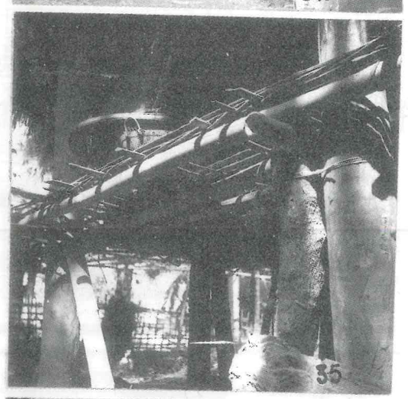
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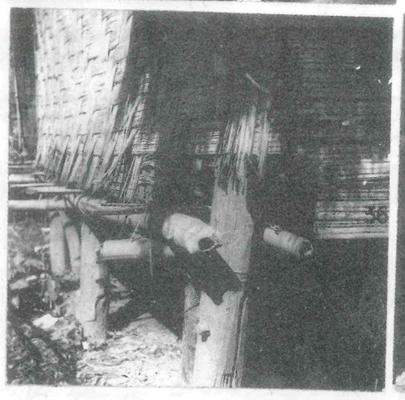
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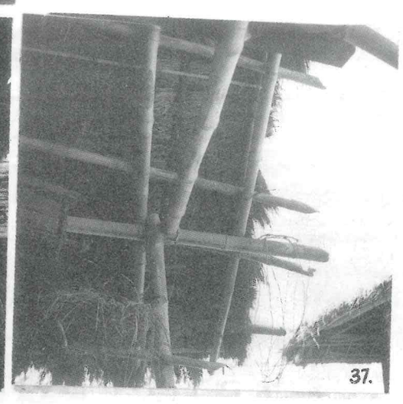
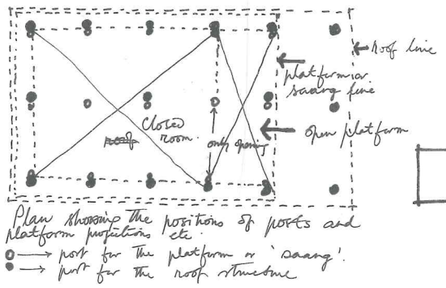
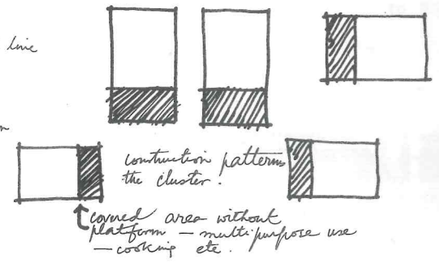
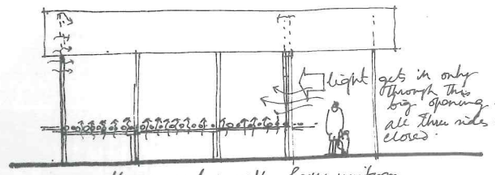

37.

34. VIEW OF THE FLOOR END FROM BELOW. LONGER SIDE OF THE HOUSE.
35. VIEW OF THE FLOOR END FROM BELOW. SHORTER SIDE OF THE HOUSE.
36. JUNCTION OF WALL PANELS AT CORNER. NOTE THE BOTTOM END OF WALL PANELS AND REFLECTION OF THE `DAO' ON THE CUT ENDS OF BAMBOOS.
37. CONSTRUCTIONAL DETAILS AT ROOF END. UNDISCIPLINED, IMMATURED AND CARELESS.



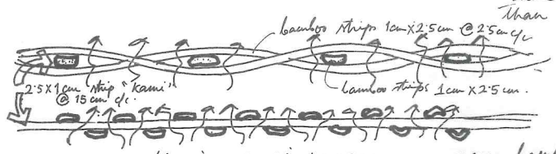
Plan showing the positions of posts and platform projection etc.
→ post for the platform or `saang'.
→ post for the roof structure



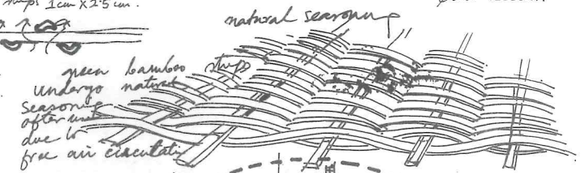


woven floors and walls have uniform perforations through which air passes in. Summer it is pleasant but winter is not comfortable. These perforations are more than 20% in the floor.

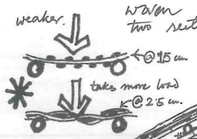

cross section



woven flooring 2 air passage two sections at ⊥r to each other.



green bamboo strips undergo natural seasoning after use due to free air circulation

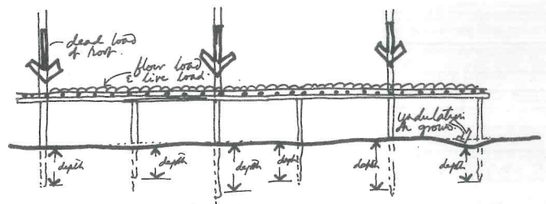


Cross section of the house.
A careless construction — no measuring tape is used — no plumbing — The material is not to be blamed for the carelessness of the construction. It is the man who builds it.

System of weave has caused the closer strips at floor to be placed along the two cross beams which is weaker than when it is placed across the cross beams

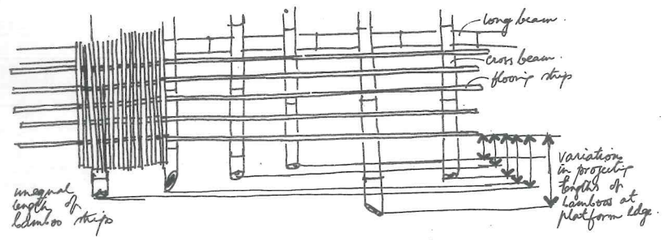
READING OF THE MATERIAL.

OBSERVATION : A HOUSE ON A PLATFORM (MIRI SAANG-GHAR.).

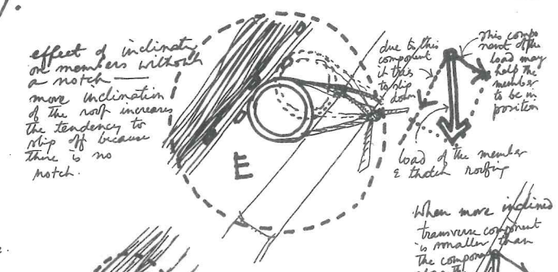


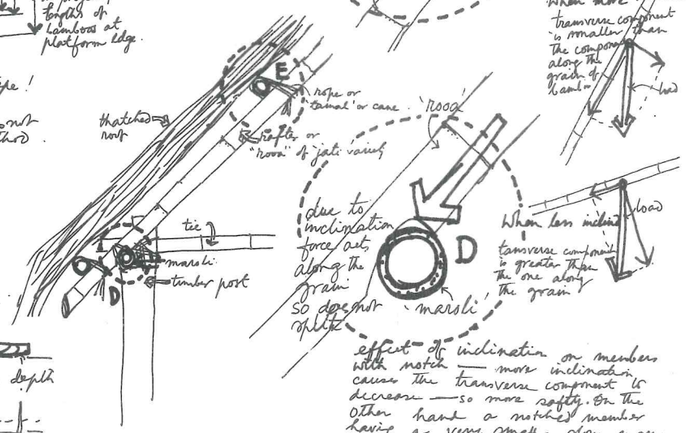
different depths of anchored burying of posts into the ground causes unequal settlements. The builder keeps the tops of the posts level adjusting the depth of burying and note by cutting the lengths of posts. Undulations in ground cause water collection which after percolating into the ground effects the settlement of posts.

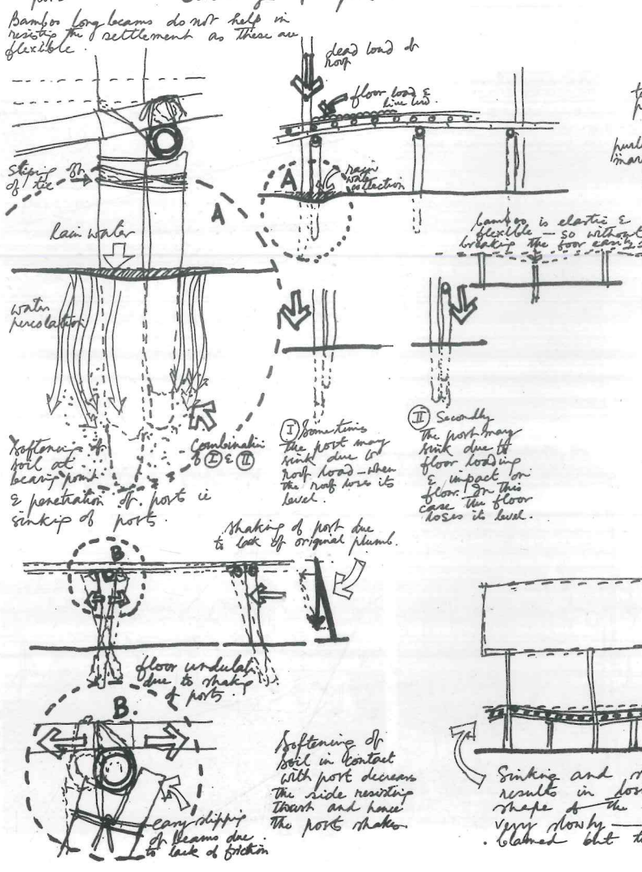
Sinking of posts.

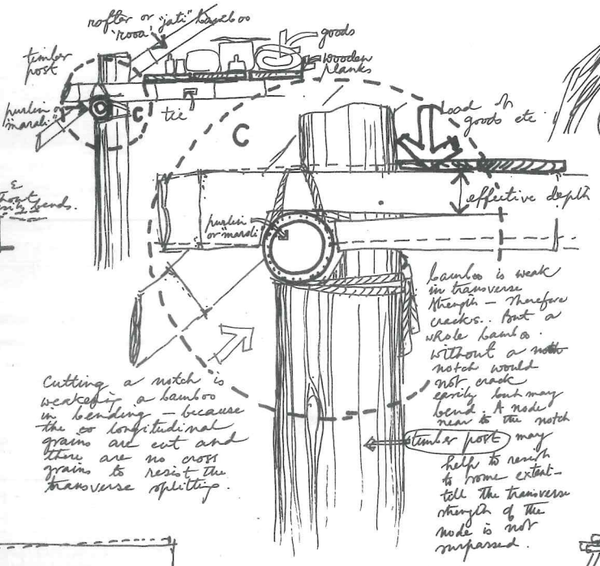


Carelessness → They never use a measuring tape! reflection of the tool used for shaping the building material. Cutting in equal length does not cost extra. No discipline in construction method.

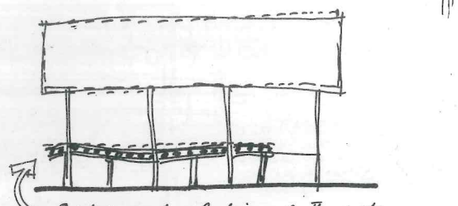




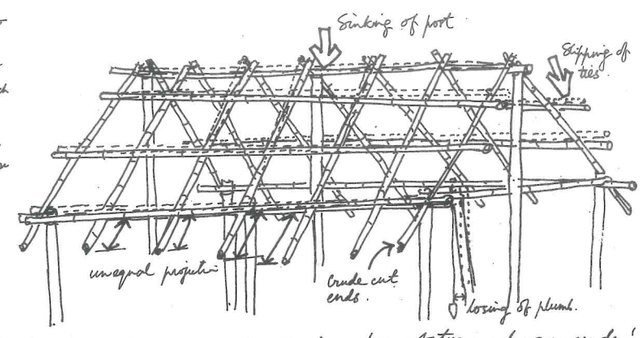




Cutting a notch is weakening a bamboo in bending — because the cc longitudinal grains are cut and there are no cross grains to resist the transverse splitting.



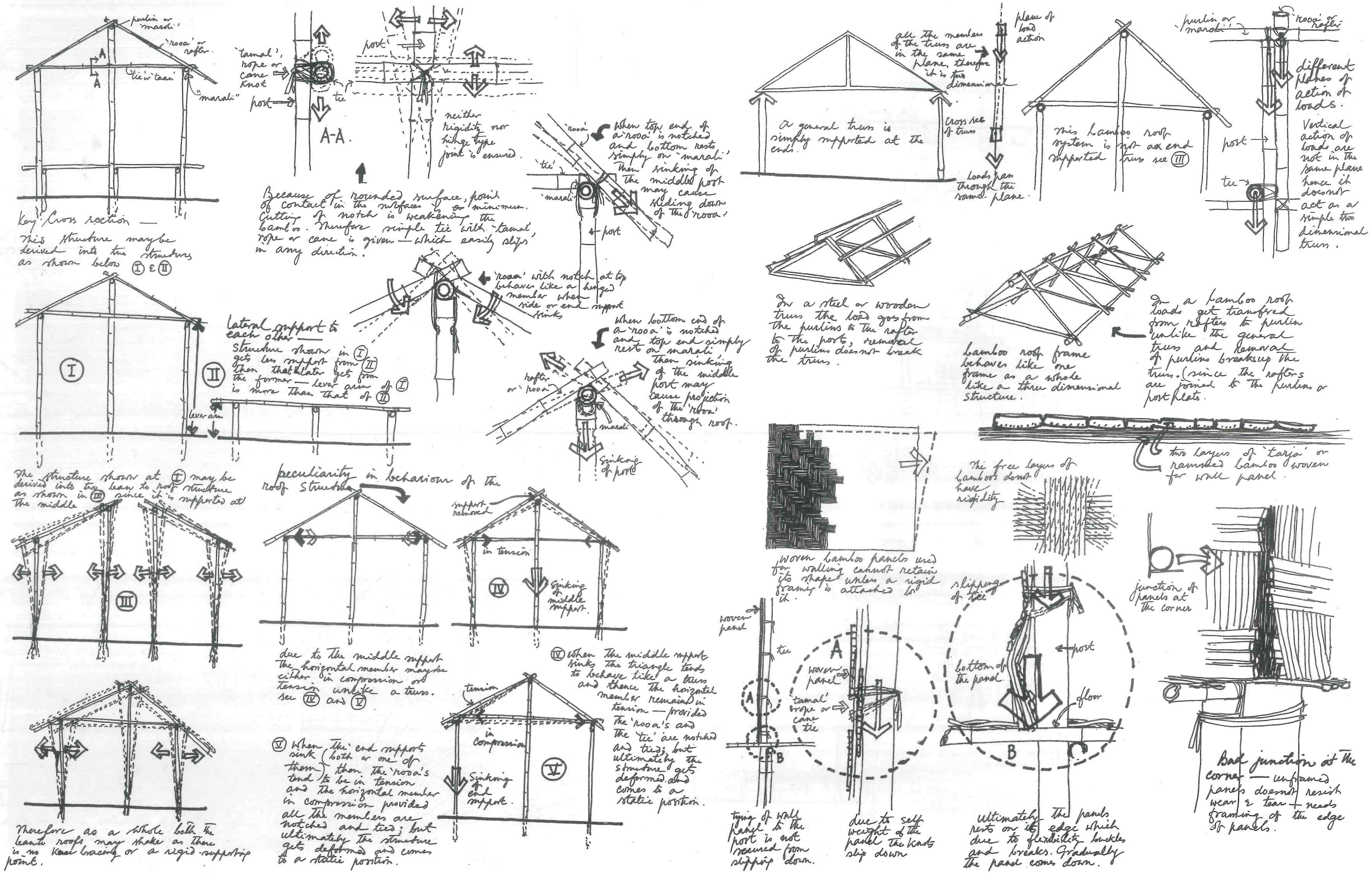
Sinking and shaking of the post results in losing the original shape of the structure. This happens very slowly — The material is not to be blamed but the builders who build it.



The ways for which the structure loses status — becomes crude!
Losing of form of the structure → slipping off of various members — losing of verticality — sinking of supports — lack of uniformity of members — reflection of the tool used for shaping the structure etc.

READING OF THE MATERIAL.

OBSERVATION : A HOUSE ON A PLATFORM (MIRI SAANG-GHAR).



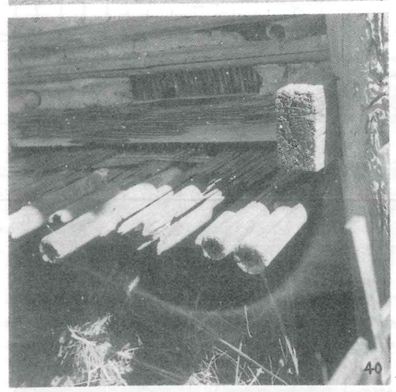
A SYSTEM OF BUILDING CONSTRUCTION WITH BAMBOO AS THE PRINCIPAL MATERIAL.

READING OF THE MATERIAL.
OBSERVATION : A GRAIN STORE (BHANRAAL GHAR).


38


39

38. VIEW FROM FRONT. BAMBOO REINFORCED MUD WALL WITH TIMBER FRAMING. THIS STORE IS 60 YEARS OLD.
39. CLOSE VIEW OF THE BAMBOOS USED FOR REINFORCING THE MUD WALL TOGETHER WITH THE TIMBER FRAMING.
40.& 41. STRUGGLE FOR EXISTENCE WITH TIME. CLOSE VIEWS OF THE WEATHERED BAMBOOS USED FOR THE FLOORING. NOTE WEATHERED TIMBERS WHICH CONVINCE THE EQUAL LASTING PERIOD OF BOTH THE MATERIALS UNDER SIMILAR CIRCUMSTANCES.
42.& 43. EXTERNAL VIEWS OF ANOTHER SIMILAR GRAIN STORE OF 40 YEARS AGE. BAMBOOS PROJECTED ARE LATERALLY SUPPORTED BY THE TIMBER POST WHILE RETAINING GRAINS INSIDE. A FINE EXAMPLE OF CLEAN STRUCTURE.
44. MAIN PLATFORM SUPPORTED ON STONE BLOCKS FOR DAMP PROOFING. MAIN LONGITUDINAL SPANNING OF TIMBER AND SHORT CROSS SPANNING OF BAMBOO.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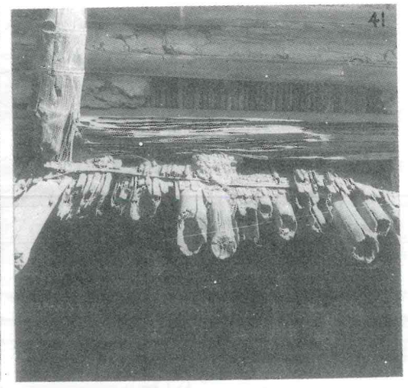
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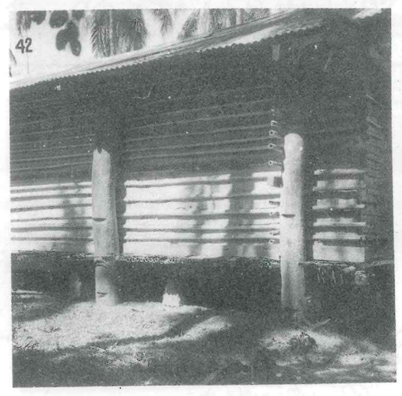
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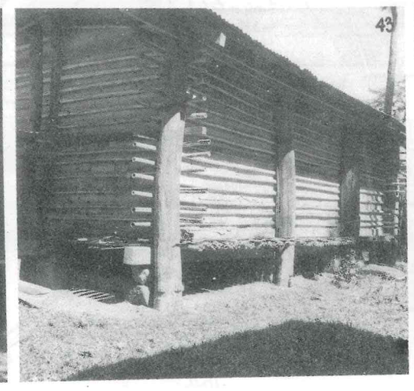
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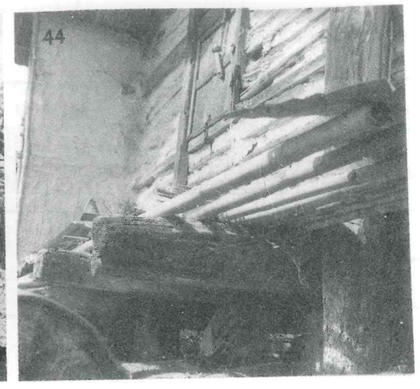
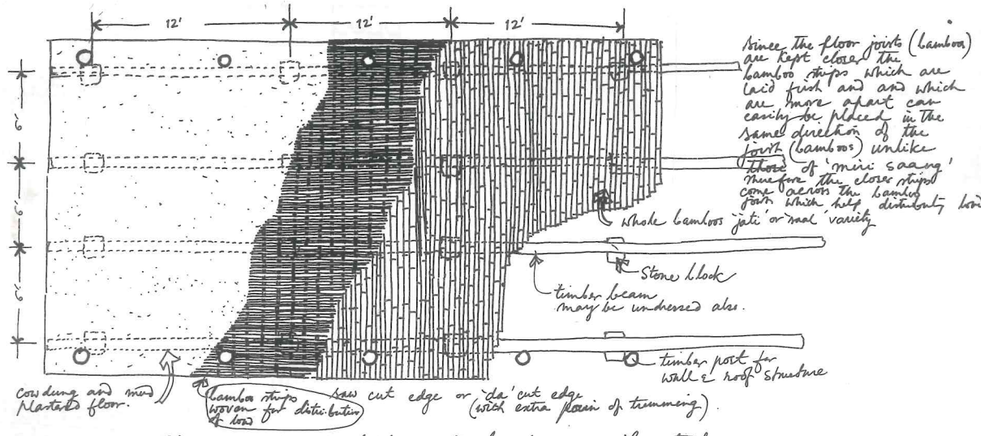

44

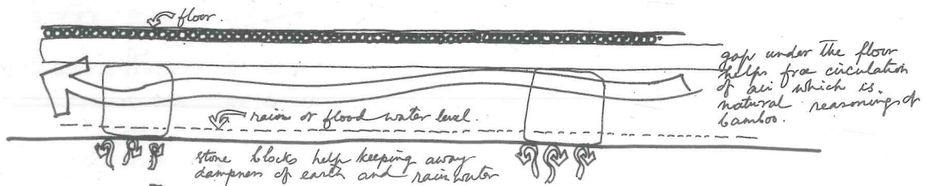
DESCRIPTION

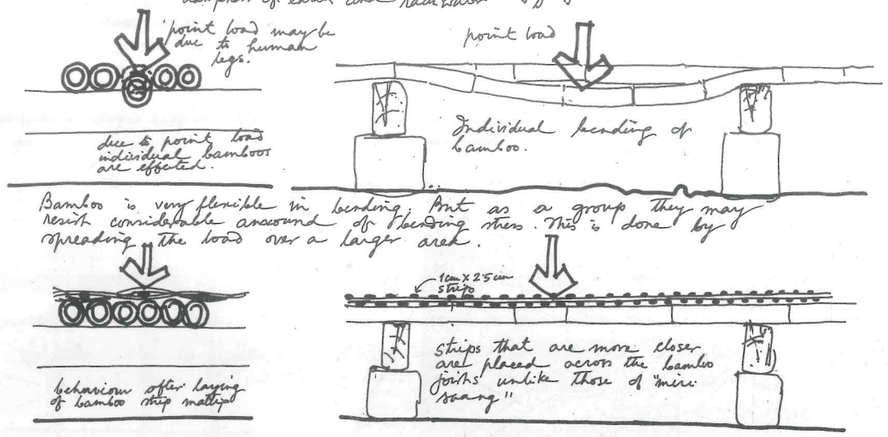
LOCATION – ASSAM.
THIS IS A COMPOSITION OF BAMBOO AND TIMBER CONSTRUCTION. A FINE EXAMPLE OF USE OF BAMBOO WITH CARE. THE FLOOR IS A PLATFORM RAISED ON STONE BLOCKS FOR DAMP PROOFING AND PROTECTION AGAINST RAIN & FLOOD WATER.
POSTS — GENERALLY TIMBER, BAMBOOS ARE ALSO SEEN.
ROOF STRUCTURE — TIMBER, BAMBOO OR BOTH.
ROOFING MATERIAL – C.I. SHEETS OR THATCH.
FLOOR — TIMBER, BAMBOO AND MUD.
DOOR — 4'X4' OPENING WITH WOODEN SHUTTER.
WINDOW — NIL.
WALL — TIMBER, BAMBOO AND MUD PLASTER.
HEIGHT — ONE FLOOR ON PLATFORM.
FOUNDATION — POSTS ARE SIMPLY BURIED INTO GROUND AND THE PLATFORM RESTS ON STONE BLOCKS.
LIFE – 60 TO 70 YEARS.

READING OF THE MATERIAL.
OBSERVATION : A GRAIN STORE (BHANRAAL GHAR).



This is a fine example of timber and bamboo composite structure — more disciplined — more scientific.

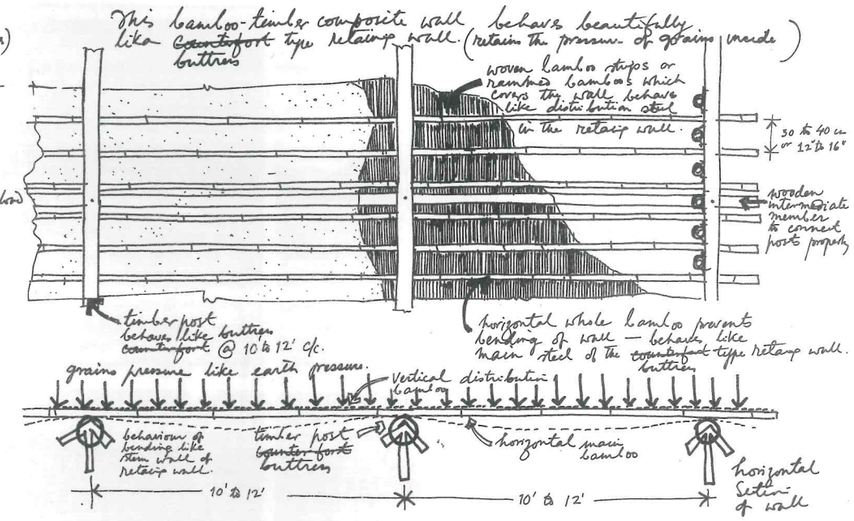




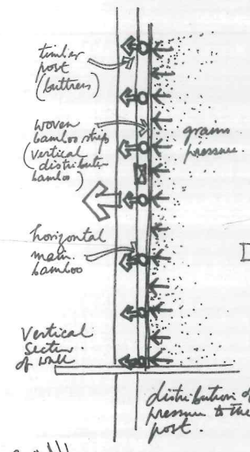
Bamboo is very flexible in bending, but as a group they may resist considerable amount of bending stress. This is done by spreading the load over a larger area.

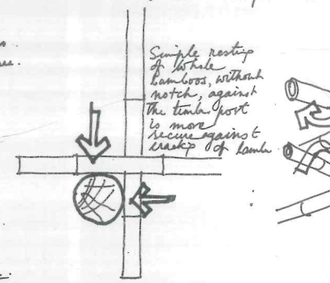
due to laying of bamboo strip & matting the load gets distributed over larger area covering more member of bamboos — then it reach more load.

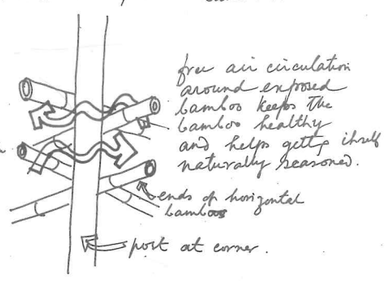
This bamboo-timber composite wall behaves beautifully like counterfort type retaining wall. (retains the pressure of grains inside)
buttress

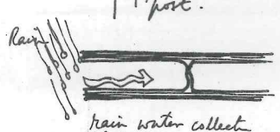


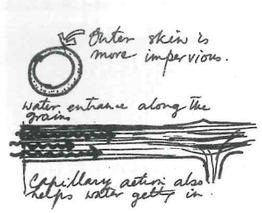
Buttress type retaining cum wall construction makes the whole structure strong. This grain store is an individual structure separated from the main living house. For security of grains stored inside, this structure got extra attention and hence structure is also superior to many other bamboo structure.







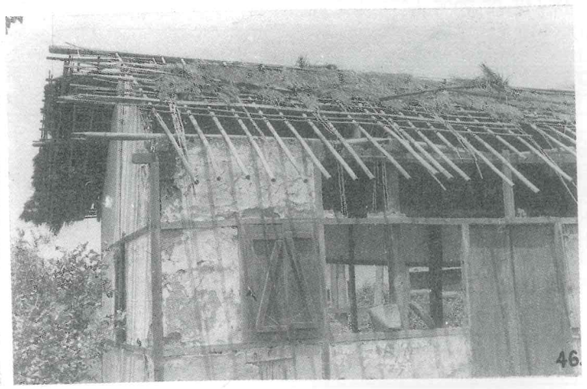




Cut ends of bamboos when exposed to atmosphere are affected by rainwater moisture etc. Main why in these structures bamboo always start rotting from the exposed cut ends.

READING OF THE MATERIAL.
OBSERVATION : A TYPICAL RESIDENTIAL HOUSE.


45.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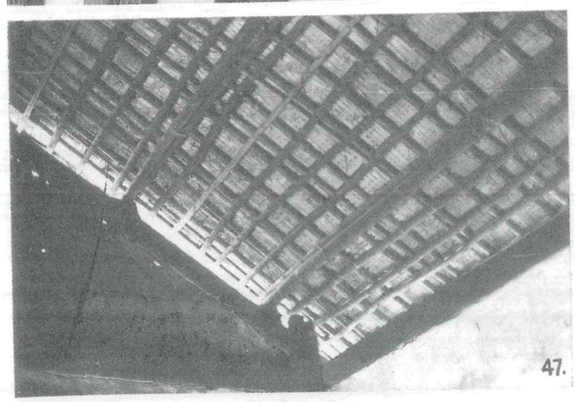
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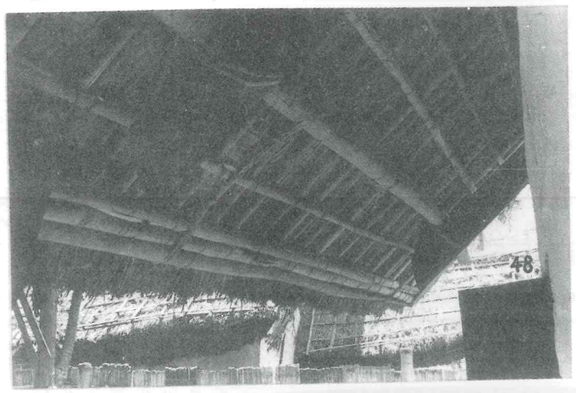
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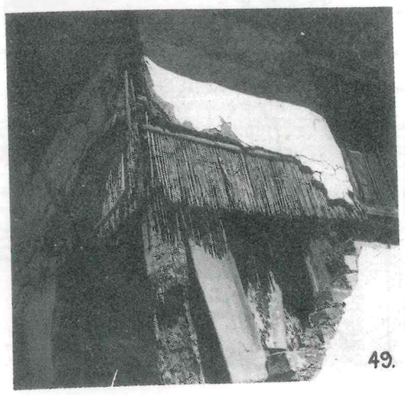

49.

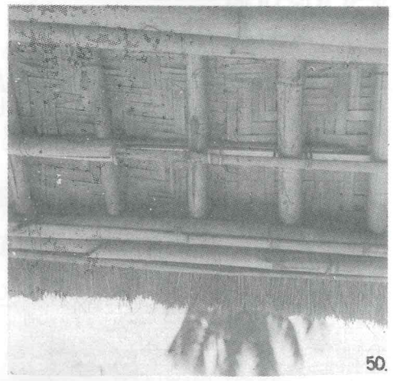
45. EXTERNAL VIEW OF A TIMBER-BAMBOO COMPOSITE HOUSE.
46. BAMBOO ROOF ON TIMBER SUPPORT. LASTS EQUALLY LONGER WITH TIMBER THAN ANY OTHER PART OF THE HOUSE.
47. KITCHEN CEILING FROM INSIDE. THIS LASTS FOR 70 TO 75 YEARS. TIMBER SUPPORTS FAIL FIRST. THE PROBABLE REASON IS THE EFFECT OF SMOKE.
48. EVE DETAIL. HORIZONTAL OVERHANG IS 2'6" OR 75CM.
49. WEATHERED CORNER OF EXTERIOR WALL OF A 60 YEARS OLD HOUSE. BAMBOO 'KAMI' IS SEEN STILL IN VERY GOOD CONDITION IN THE MUD WALL WHILE TIMBER POST HAS FAILED.

DESCRIPTION.

LOCATION — ASSAM.
THIS IS AN OLD 'ASSAM TYPE' TIMBER AND BAMBOO HOUSE. THESE ARE SEEN BOTH IN RURAL AND URBAN AREAS. ECONOMY OF THE STRUCTURE TURNS IT INTO LOW COST HOUSE IN URBAN AREAS.
POSTS — TIMBER.
FOUNDATION — CONCRETE AND BRICK FOUNDATION, POSTS CLAMPED TO CONCRETE OR SIMPLY PILED.
WALL — TIMBER FRAMED, BAMBOO REINFORCED MUD OR CEMENT PLASTERED.
FLOOR — EARTHEN OR B.B.L.C. WITH CEMENT PLASTERING.
ROOF STRUCTURE — TIMBER AND BAMBOO.
ROOFING MATERIAL — THATCH.
PLINTH — EARTHEN OR BRICK.
DOOR — TIMBER PANELLED.
WINDOW — TIMBER PANELLED.
HEIGHT — GROUND FLOOR STRUCTURE.
COST — RS. 5'50 TO 6'00 PER SQ. FOOT.
LIFE — 35 TO 40 YEARS.

READING OF THE MATERIAL.

OBSERVATION : A TYPICAL RESIDENTIAL HOUSE.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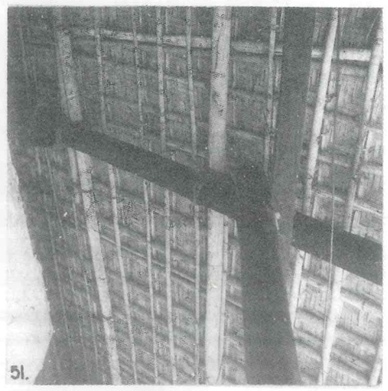
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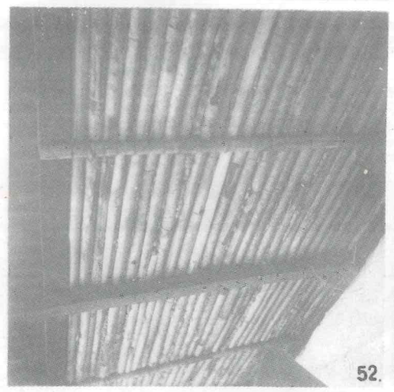
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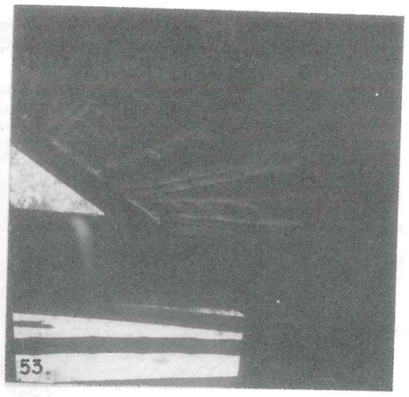
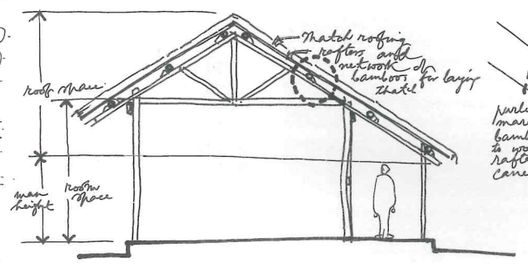
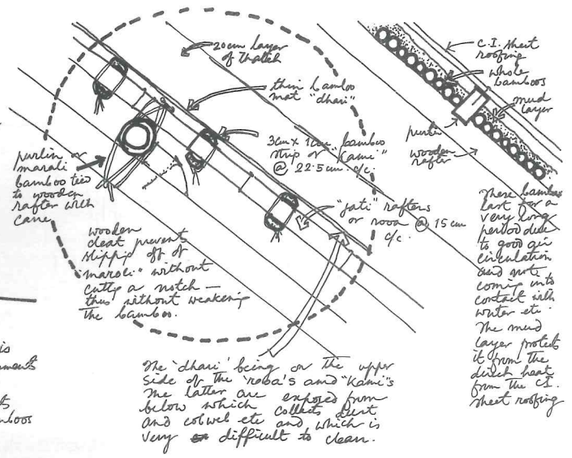
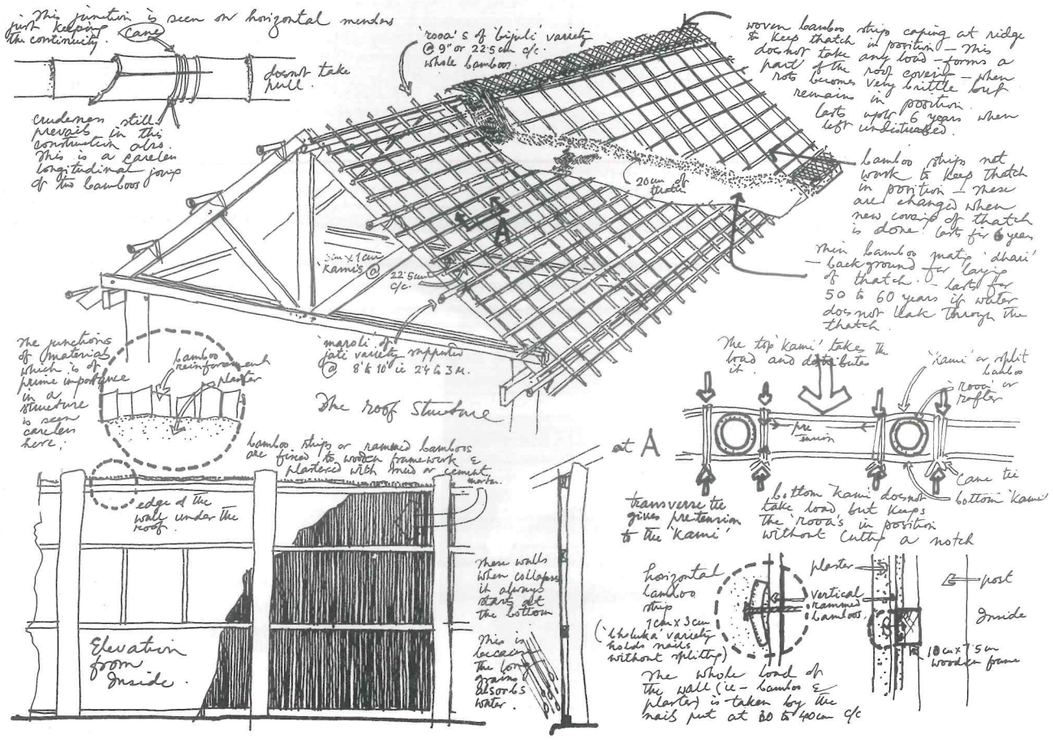

53.

50. EVE DETAIL OF ROOF. NOTE THE RAFTERS AND PURLIN.
51. CEILING. THE UNDERSIDE OF A VERANDAH ROOF. BAMBOO PURLINS AND COMMON RAFTERS ON TIMBER PRINCIPAL RAFTERS.
52. BAMBOO CEILING. THESE BAMBOOS WERE REUSED WHEN THEY WERE ALREADY 20 YEARS OLD IN A KITCHEN CEILING. PRESENT AGE IS 40 YEARS.
53. KITCHEN CEILING OF A 60 YEARS OLD HOUSE. THE BAMBOO CEILING WITH MUD PLASTER IS STILL HOLDING GOOD WHILE FEW TIMBER JOISTS HAVE FAILED.

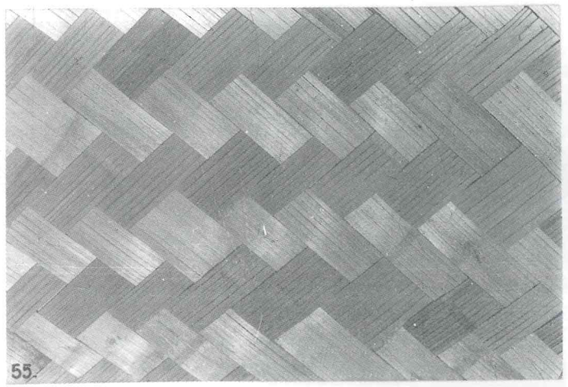






READING OF THE MATERIAL.
OBSERVATION: USE OF BAMBOO PANELS IN HOUSES.


54.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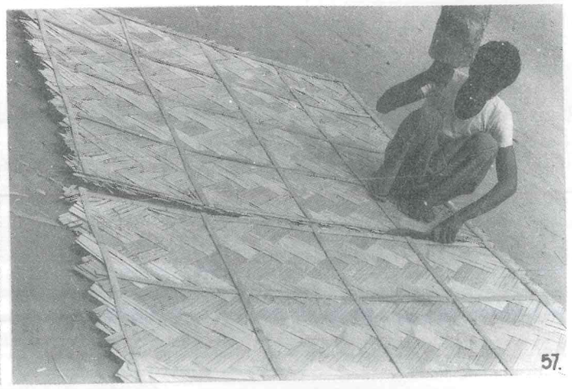
56.


57.

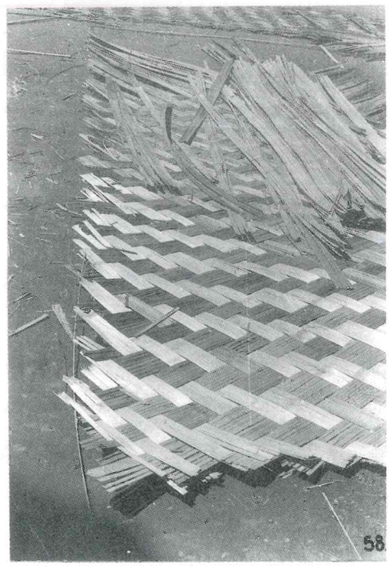
54. RAMMED AND OPENED BAMBOOS STACKED BEFORE WEAVING INTO PANELS.
55. WOVEN PANEL OF BAMBOO. A PARTIAL VIEW.
56. ROLLED UP WOVEN PANELS: SHOWS FLEXIBILITY.
57. CUTTING OUT INTO SIZES REQUIRED. CUT END MAY BE TRIMMED WITH A CHISEL.
58. WEAVING OF THE PANELS.

DESCRIPTION.

THESE ARE MADE OF 'TORAI' VARIETY OF BAMBOO. VERY ECONOMICALLY USED FOR WALL PANELLING. HOWEVER, SECURITY IS LESS AND NOT WEATHER-PROOF. CANNOT BE PLASTERED ON THE SMOOTHER SURFACE. IF USED IN CEILING OR INTERNAL PANNELING IT LASTS FOR A VERY LONG PERIOD. ALSO THESE ARE USED FOR COMPOUND HIGH FENCE, DOOR-WINDOW PANELS, PARTITION WALLS ETC.

LASTING PERIOD. UPTO **3** YEARS IF EXPOSED AND UNCOVERED. UPTO **6** YEARS IF USED FOR EXTERNAL WALL PANELLING AND EXPOSED TO RAIN WATER AND **12** YEARS IF PROTECTED FROM IT. UPTO **20** YEARS IF USED INTERNALLY AND NOT LESS THAN **40** YEARS WHEN PROTECTED WITH PAINT OR VARNISH.

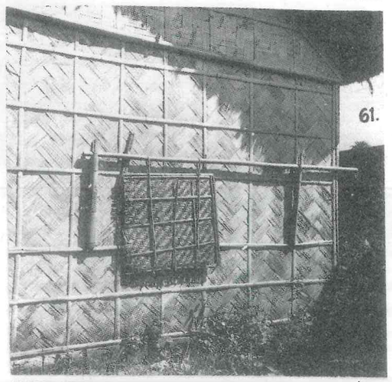
COST. PANELS MADE FROM OUTER HALF OF BAMBOO SKIN — **18** PAISE/SQ.FT. AND THAT OF THE INNER HALF — **14** PAISE/SQ.FT.


58.

READING OF THE MATERIAL.
OBSERVATION : USE OF BAMBOO PANEL IN HOUSES.


59


60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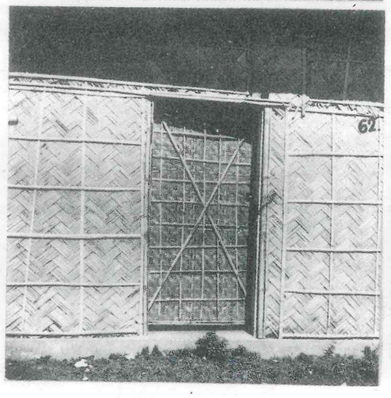
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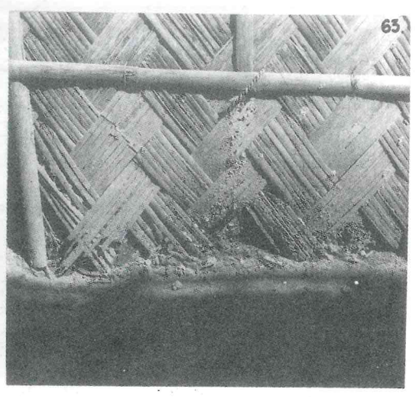
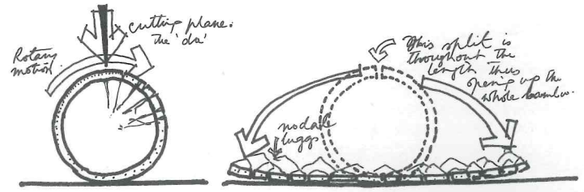
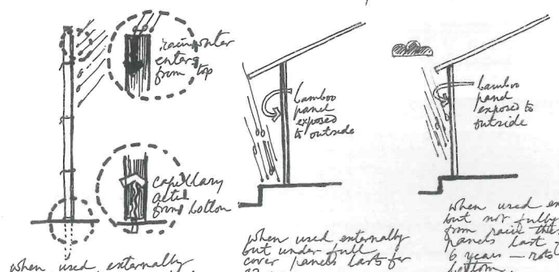

63.

59. EXERIOR OF A TIMBER FRAMED AND BAMBOO PANELLED HOUSE.
60. USE OF BAMBOO PANELS IN A BAMBOO FRAMED HUT. NOTE THE WINDOW OPENING (SHUTTERS INSIDE).
61. A VERY WEAK CONSTRUCTION OF WINDOW SHUTTER (EXTERNAL).
62. BAMBOO PANELLED AND FRAMED DOOR SHUTTER. NOTE THE LOCKING SYSTEM.
63. WEATHERING OF 1½ YEARS TIME DUE TO EARTH'S CONTACT. A MISUSE.



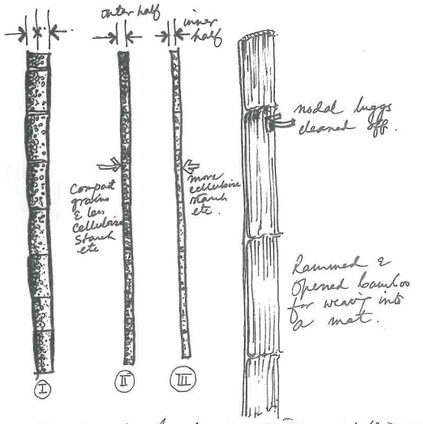
Opening up of the whole bamboo is done first by splitting in from side — these splits are done along the grain but not in the same line throughout the entire length. Ultimately one full length splitting is done and the bamboo is opened up.



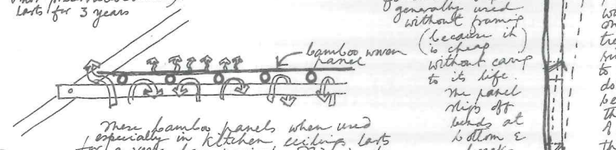
when used externally & exposed to sun & rain it is like pushing the material into the jaws of death. (when not preservative treated) Lasts for 3 years

when used externally but under full cover panels lasts for 12 years.

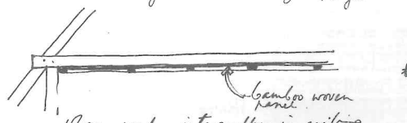
when used externally but not fully covered from rain these panels last for 6 years — rots from bottom.



The opened bamboo is further splitted into two halves along the length. Towards the outer skin grains are more dense and less quantity of cellulose lignin etc. Therefore the outer half (II) stands better in wear & tear and less liable to insect attack. The case is reverse in (III).

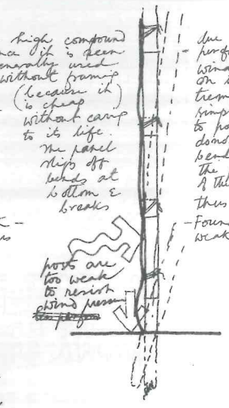


These bamboo panels when used especially in kitchen ceiling lasts for a very long period. This is due to effect of smoke & dry air circulation — insects never get it — lasts for 70 years

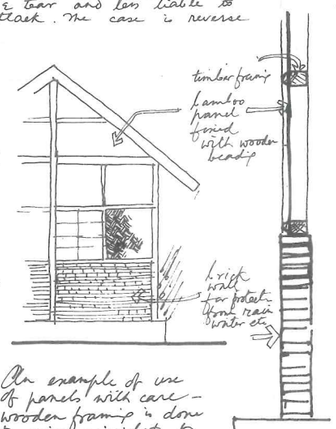


When used internally in ceiling and given a coating of paint/or varnish it lasts for 40 years. Here look beautiful when framed with battens and edges trimmed with a chisel

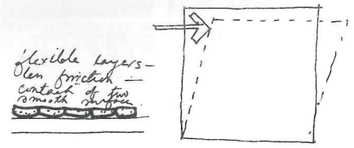
In high compound fence it is seen generally used without framing (because in) to check cattle without caring to its life the panel slips off behind at bottom & breaks



due to less perforations wind pressure on these are tremendous, simple knots to ports cannot resist bending of the plane & the wall then collapses. — Foundations weak.

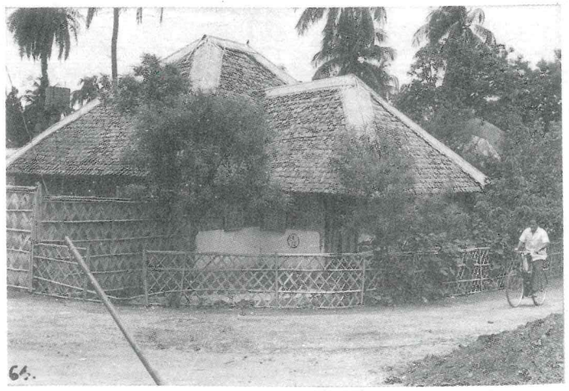


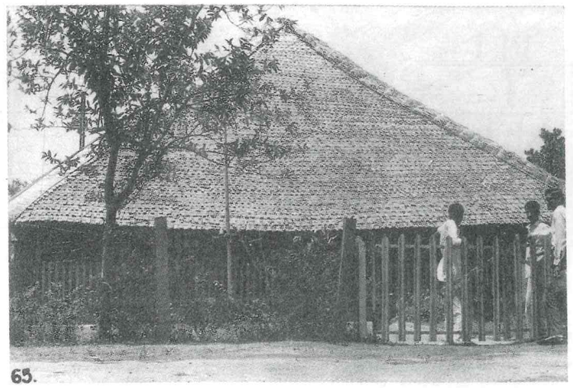
An example of use of panels with care — wooden framing is done to give rigidity to the panels. If protected with preservative, even when it is used externally it lasts for about 15 years easily.

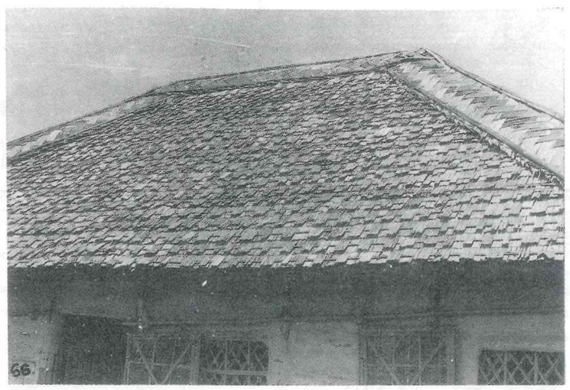


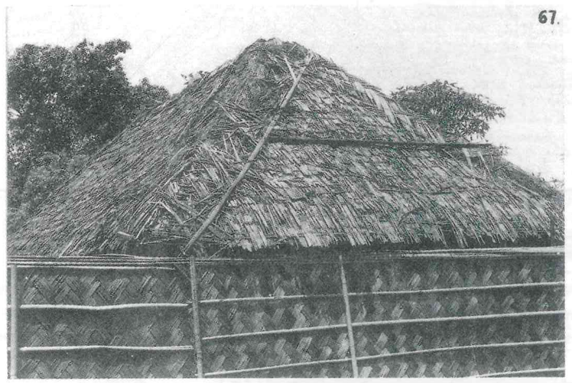
The behaviour is like a cloth — woven — flexible layers. — no rigidity. Shear for deformation happen easily unless it is framed out with a rigid material

READING OF THE MATERIAL.
OBSERVATION : A TYPICAL ALL BAMBOO HOUSE.


64.


65.


66.


67.

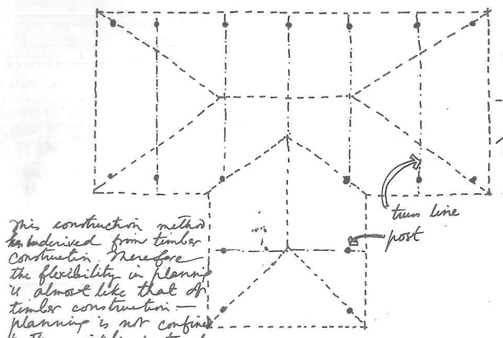
64. GENERAL VIEW OF A TYPICAL ALL BAMBOO HOUSE.
66. CLOSE VIEW OF THE ROOF. RIDGING IS OF DIAGONALY WOVEN RAMMED BAMBOO.

65. BAMBOO SHINGLE ROOF ON TIMBER STRUCTURE. NOTE THE HUGE SPACE OCCUPIED BY THE ROOF
67. WEATHERED ROOF AFTER 5 TO 6 YEARS.

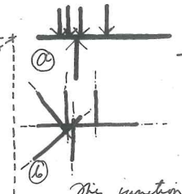
DESCRIPTION

LOCATION – ASSAM.
THIS IS A TYPICAL HOUSE CONSTRUCTION IN WHICH ALL THE COMPONENTS ARE MADE OUT OF BAMBOO. BAMBOO BEING CHEAPLY AVAILABLE THE CONSTRUCTION BECOMES ECONOMICAL. MOSTLY USED AS LOW COST HOUSING IN THE URBAN AREAS. PLANNING IS NOT CONFINED TO A RECTANGLE LIKE THAT IN THE ORDINARY BAMBOO HOUSE CONSTRUCTION.
POSTS — BAMBOO OR TIMBER.
ROOF STRUCTURE – TIMBER-BAMBOO , BAMBOO.
ROOFING MATERIAL – BAMBOO SHINGLES.
FLOOR. MA EARTHEN OR B.B.L.C. WITH CEMENT PLASTER.
PLINTH – EARTHEN OR BRICK.
DOOR – BAMBOO , TIMBER.
WINDOW – BAMBOO , TIMBER.
WALL — BAMBOO PANELS PLASTERED OR EXPOSED.
HEIGHT – GROUND-FLOOR STRUCTURE.
FOUNDATION — POSTS CLAMPED TO BRICK AND CONCRETE FOOTING OR SIMPLY PUT INTO GROUND.
COST RS. 250 TO 400 PER SQ.FT.
LIFE. 25 YEARS , WITH INTERMEDIATE REPLACEMENT OF SHINGLES.

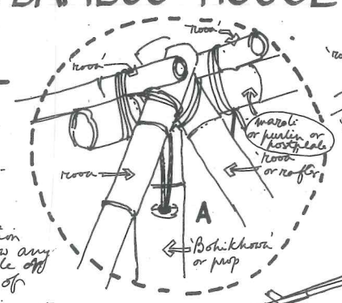
READING OF THE MATERIAL.
OBSERVATION : A TYPICAL ALL BAMBOO HOUSE.

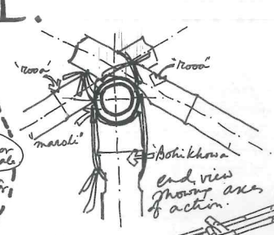


This construction method is borrowed from timber construction. Therefore the flexibility in planning is almost like that of timber construction — planning is not confined to the simple rectangle.

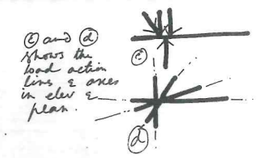


This junction does not show any definite rule of discipline of construction. @ and (b) show the axes of the different members in elev. & plan meeting at the junction.

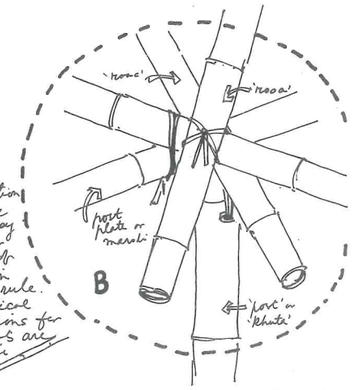




end view showing axes of action.

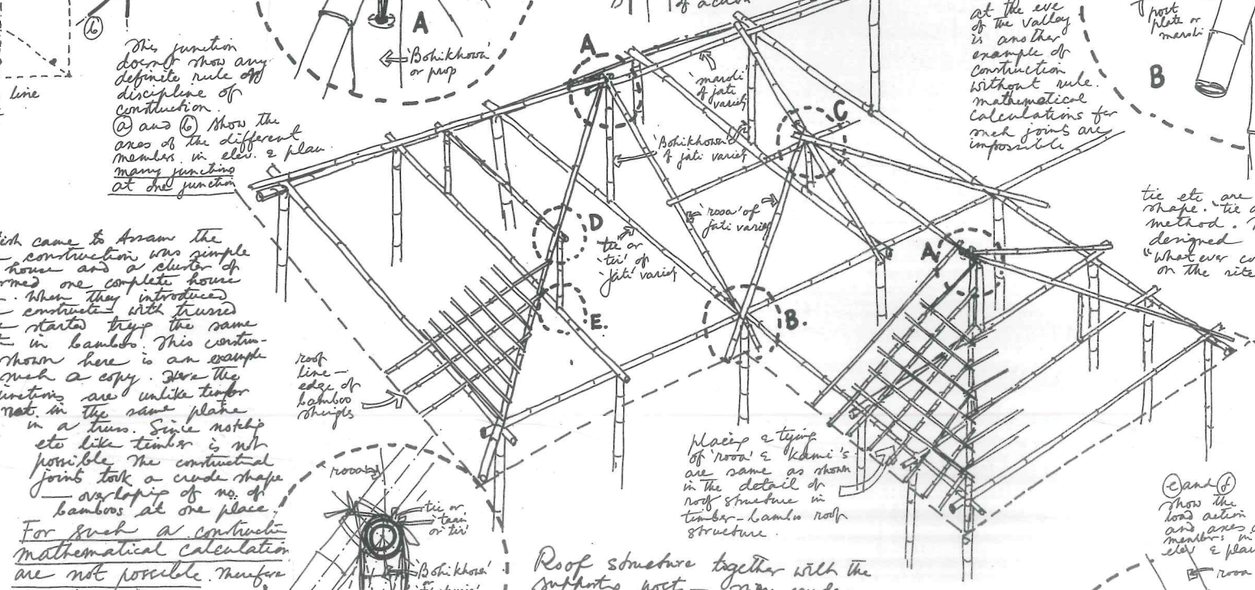


c and d shows the load action lines & axes in elev & plan.



This junction at the eve of the valley is another example of construction without rule. mathematical calculations for such joints are impossible.

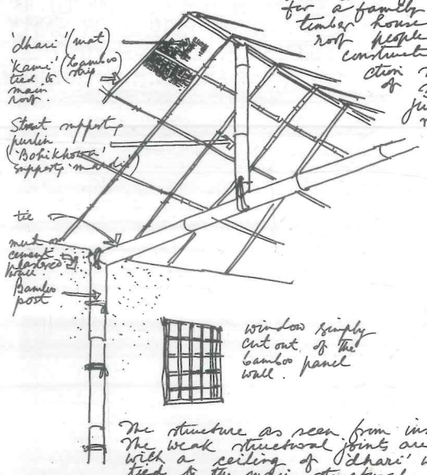
tie etc are also without shape. "tie and try" is the method. These are never designed on a paper. "Whatever comes on the way on the site — solve it" type.



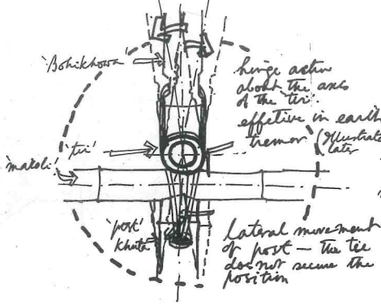
placing & tying of 'roora' & 'kami's are same as shown in the detail of roof structure in timber-bamboo roof structure.

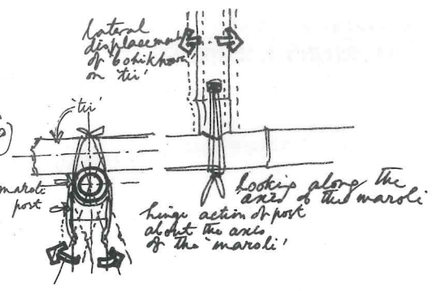
Before the British came to Assam the bamboo house construction was simple single roofed house and a cluster of such units formed one complete house for a family. When they introduced timber house construction with trussed roof people started trying the same construction in bamboo. This construction shown here is an example of such a copy. Here the junctions are unlike timber not in the same plane in a truss. Single notched etc like timber is not possible. The constructional joint took a crude shape — overlaping of no. of bamboos at one place.

For such a construction mathematical calculation are not possible. Therefore never precise.

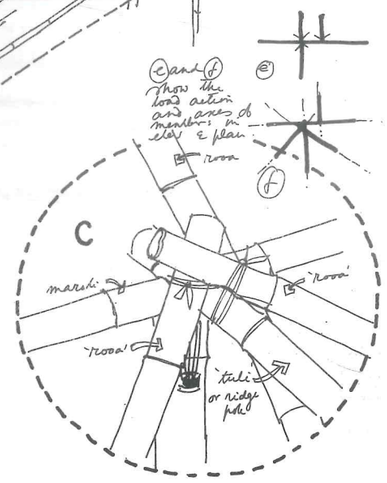


The structure as seen from inside. The weak structural joints are covered with a ceiling of 'dhari' which is tied to the main structural roof from below.





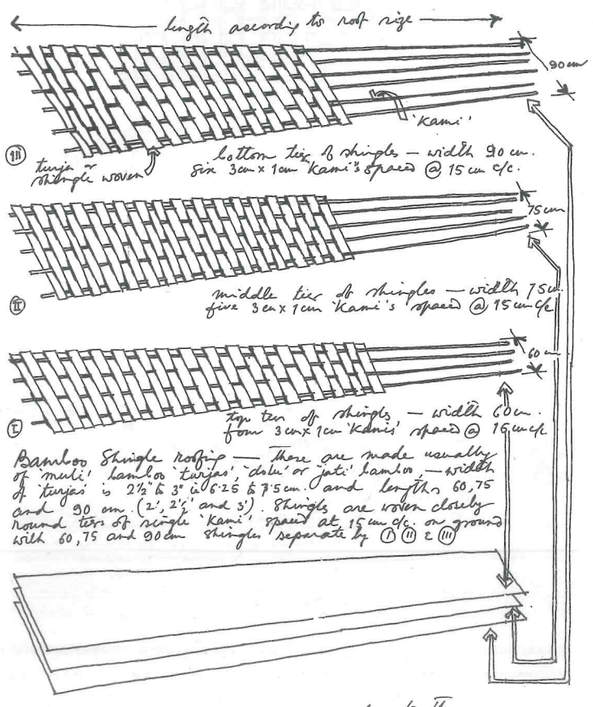
Roof structure together with the supporting post — Often crude junctions get covered when bamboo shingle is put on top and 'dhari' from bottom. Since the 'shingles' & 'dhari' are flexible, alignment is kept on the finished structure.

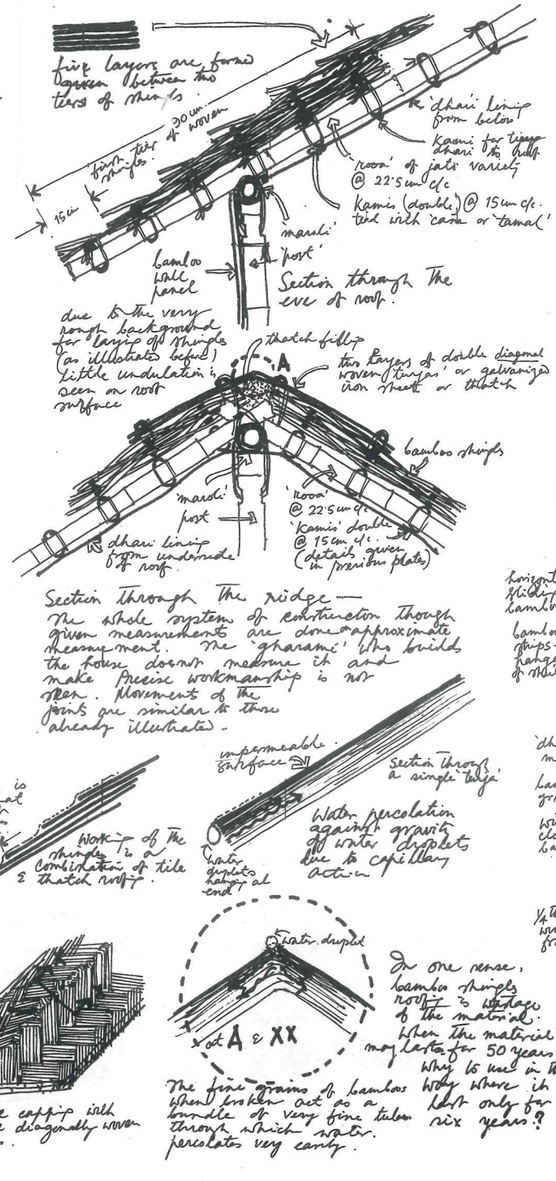


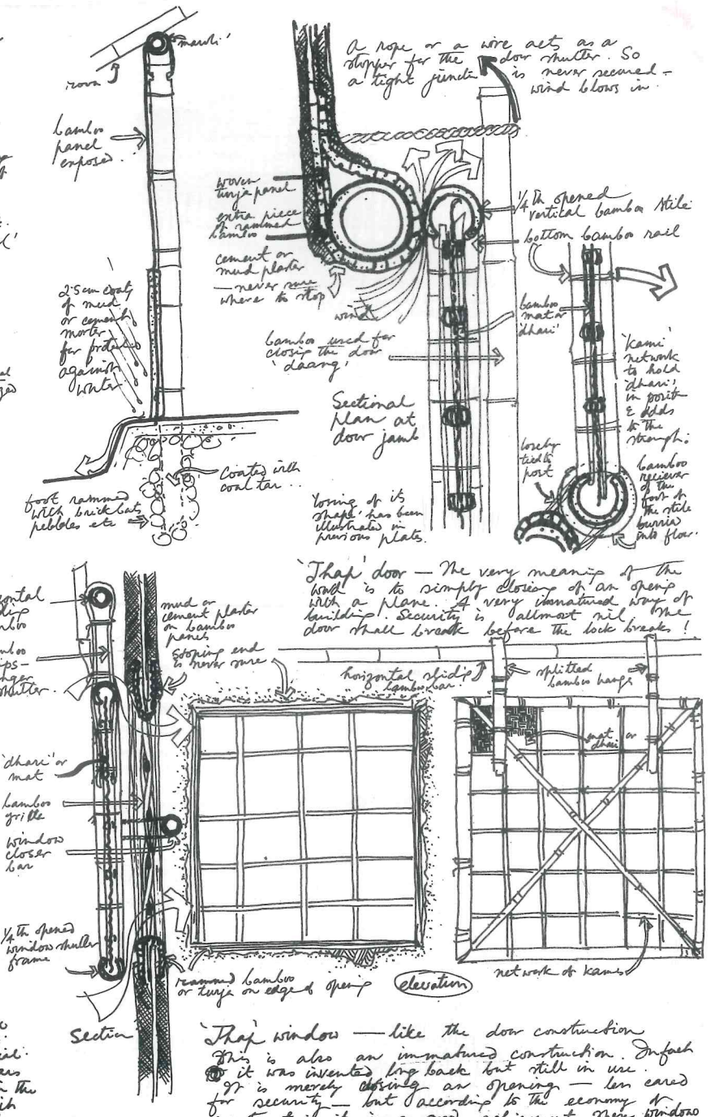
This junction is also another of the same type. As the centre lines or axes don't meet together the alignment of the ridge has to be done with bamboo shingles.

READING OF THE MATERIAL.

OBSERVATION : A TYPICAL ALL BAMBOO HOUSE.

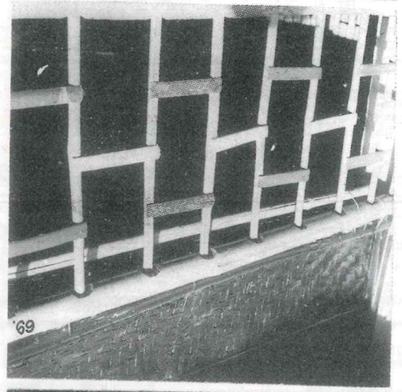




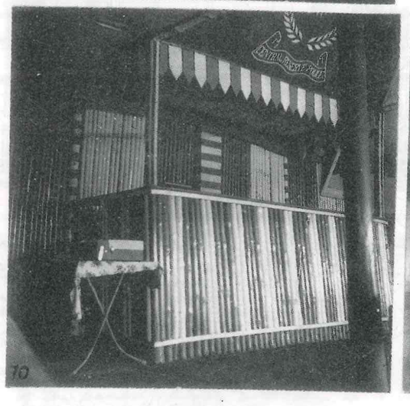


READING OF THE MATERIAL.
OBSERVATION : UTILITY OF BAMBOO IN PRESENT CONSTRUCTION.

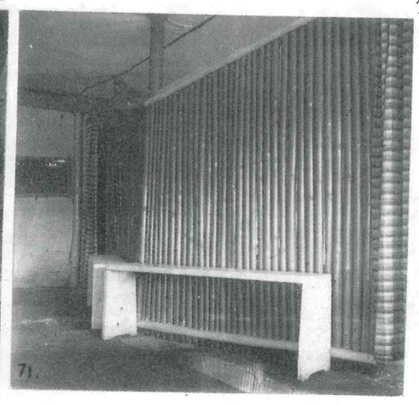
68.



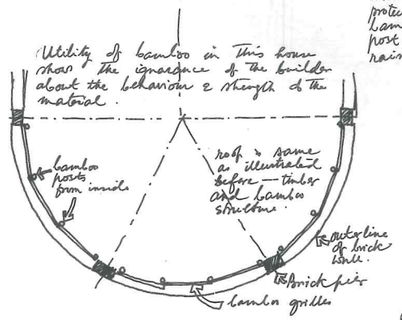
69



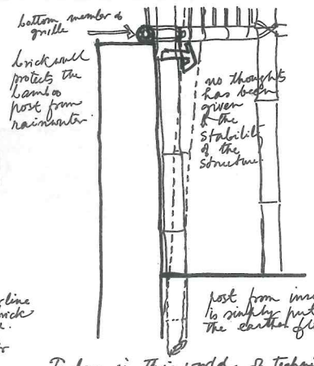
70



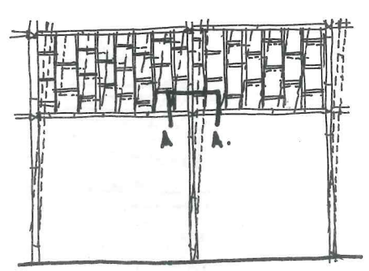
71.



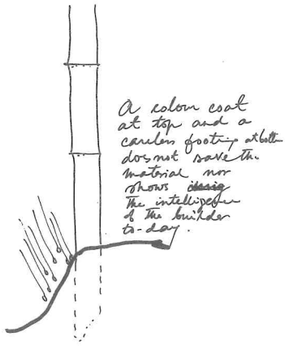
68. A HOUSE WITH BRICK PIERS AND BAMBOO AND TIMBER ROOF STRUCTURE.
69. CLOSE VIEW OF THE BAMBOO GRILLE. IMMATURE HANDLING OF THE MATERIAL.
70. A BAR COUNTER. LOSS OF CHARACTER OF THE MATERIAL.
71. A SIMPLE WHOLE BAMBOO PARTITION WALL

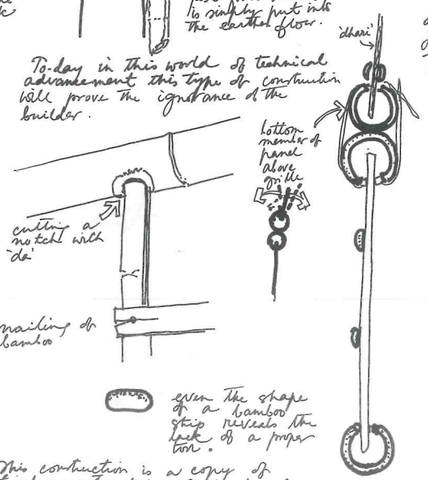


To-day in this world of technical advancement this type of construction will prove the ignorance of the builder.



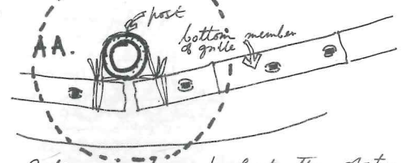
Inspite of the known fact of lack of rigidity in a bamboo joint of this type the builder has not provided anything to check it.





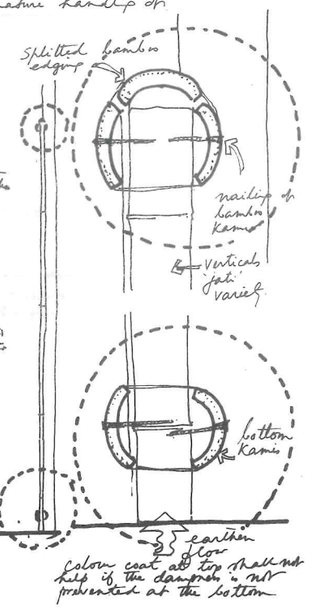
given the shape of a bamboo strip reveals the lack of a proper tension.

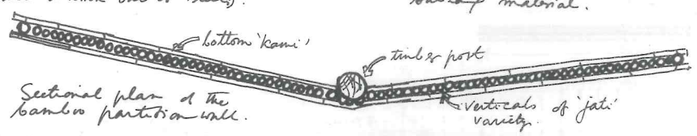
This construction is a copy of timber construction which does not hold good in bamboo since the behaviour and strength morphology is different. Why do a timber construction in bamboo? (We do not make a brick out of steel).



Extreme carelessness! hurts the status of the material — shows the immature handling of bamboo.

Observations of these constructional details compels one to say that the builder does not have a control over the material — less experienced with the material. This is what hurts the status of a building material.





Sectional plan of the bamboo partition wall.

Bamboo partition — This construction is somewhat away from goodness. — colour coat on the bamboo killed the texture & beauty of bamboo —

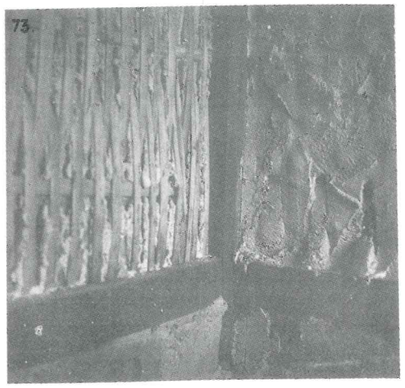
Colour coat at top shall not help if the dampness is not prevented at the bottom

READING OF THE MATERIAL.

OBSERVATION : UTILITY OF BAMBOO IN PRESENT CONSTRUCTION.

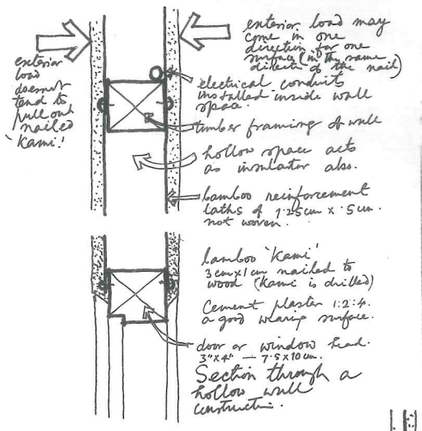
72.

73.

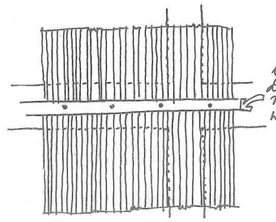


74.

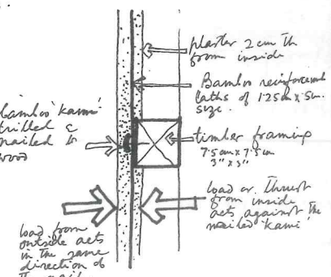
72. BAMBOO REINFORCEMENT IN A TIMBER FRAMED HOUSE. THESE BAMBOOS LAST LONGER THAN THE TIMBER FRAME.
73. FIRST COAT OF CEMENT PLASTER ON BAMBOO REINFORCEMENT.
74. EXTERIOR VIEW OF HOUSES WITH BAMBOO REINFORCED CEMENT PLASTERED WALL.
75. HOUSE WITH BAMBOO REINFORCED HOLLOW WALL SYSTEM.



75.

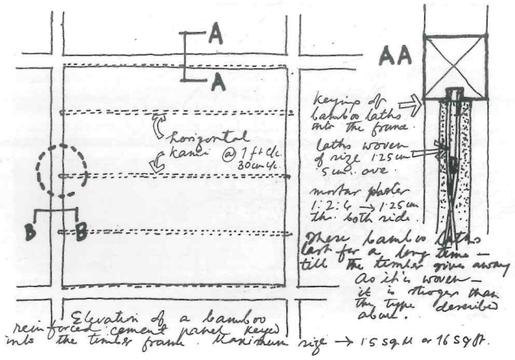


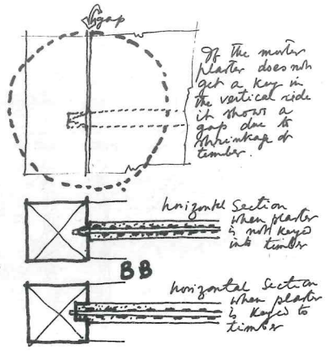
elevation of bamboo laths fixed to timber frame maximum unsupported area is 1·5 sq.M ie 16 sq.ft.



Section — Single wall construction — doesn't have a good insulating capacity due to thinness.

76.





77.

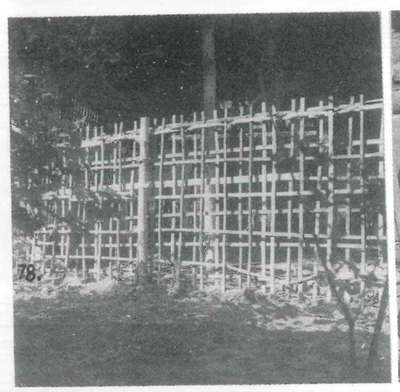
These are the most successfull practices of bamboo utility in building construction of Assam to-day.

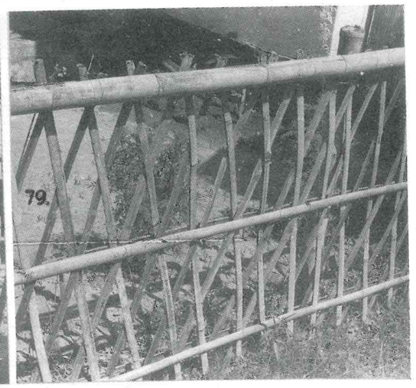
76. INTERIOR OF THE HOUSE AT TOP. HOLLOW WALL SYSTEM WITH CONCEALED ELECTRIC INSTALLATION.
77. EXTERIOR OF A HOUSE WHEN BAMBOO LATH IS FIXED TO THE OUTER SIDE OF THE TIMBER FRAME.

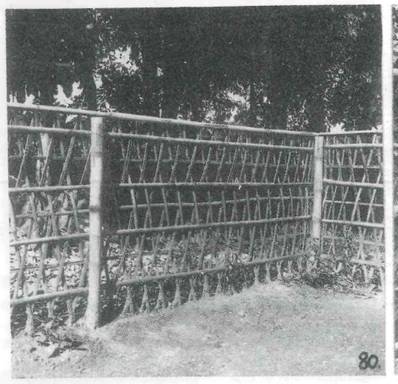
A SYSTEM OF BUILDING CONSTRUCTION WITH BAMBOO AS THE PRINCIPAL MATERIAL.

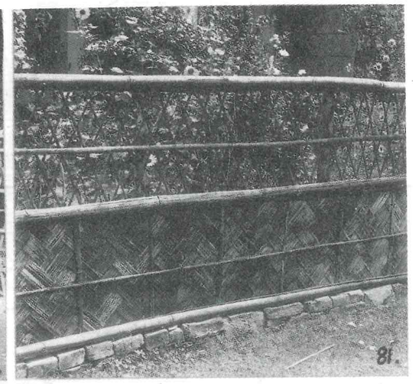
READING OF THE MATERIAL.

OBSERVATION : OBJECTS OTHER THAN HOUSES.







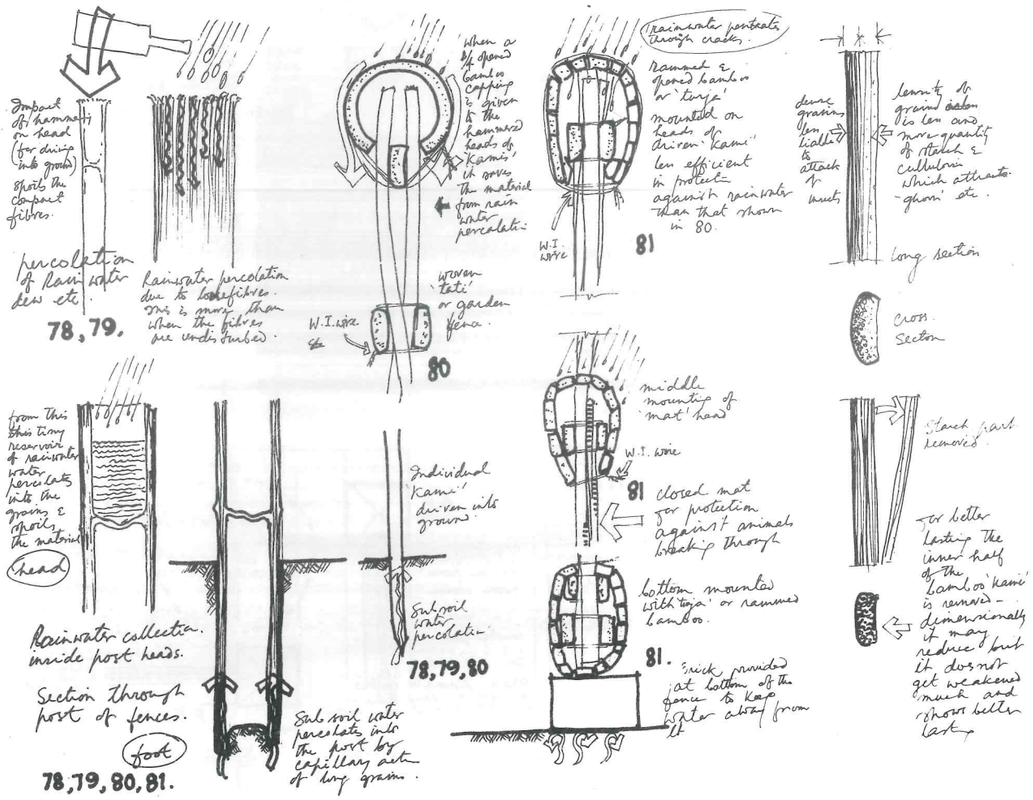


I 6 ALL A MATTER OF DEGREE OF CARE FOR A MATERIAL.

THESE FOUR FACES OF GARDEN FENCE DEPICT THE DEGREE OF IMPORTANCE GIVEN TO THEM.

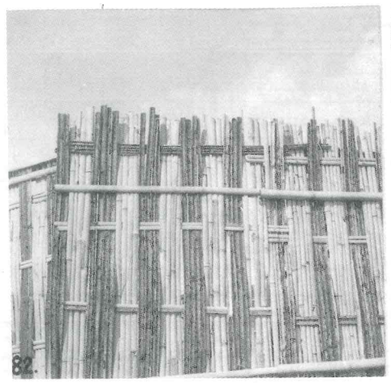
78. ABUNDANCE OF MATERIAL – LESS CARE FOR ITS LIFE – SAVING OF TIME AND LABOUR – LOW INITIAL COST. LASTS FOR 1 TO 1½ YEARS.
79. ECONOMY OF MATERIAL – MORE COVERAGE WIT LESS MATERIAL – LOW INITIAL COST – LESS CARE FOR LIFE. LASTS FOR 1 TO 1½ YEARS.
80. A LITTLE SYMPATHY TOWARDS THE MATERIAL – A LITTLE CARE – A LITTLE MORE DISCIPLINE. INITIAL COST IS MORE BUT LIFE IS MORE. LASTS FOR 2 TO 2½ YEARS.
81. A BETTER CARE AND MORE SYMPATHY – A BETTER UNDERSTANDING. INITIAL COST IS MORE BUT LASTS LOGER – UPTO 6 YEARS.

HENCE IT IS THE CARE TAKEN THAT DECIDES THE LIFE OF A MATERIAL.



READING OF THE MATERIAL.

OBSERVATION: OBJECTS OTHER THAN HOUSES.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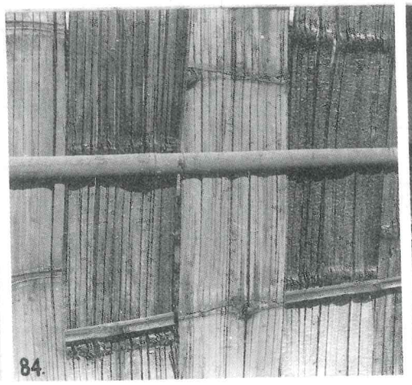
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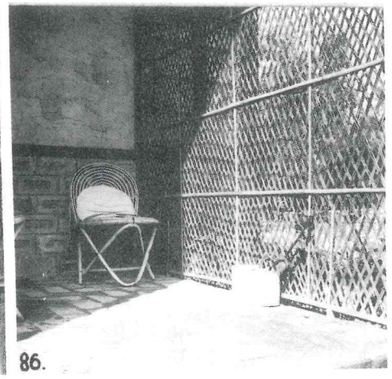
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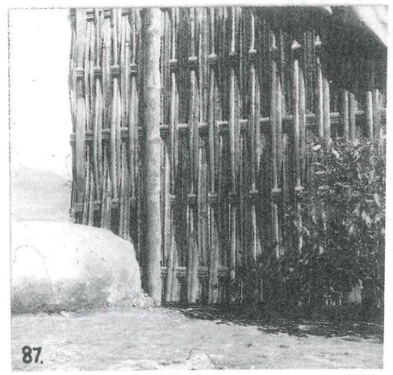
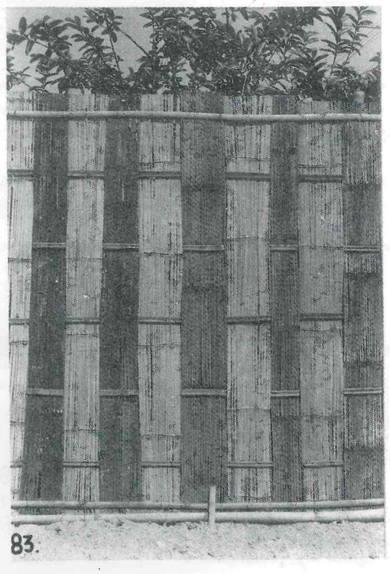
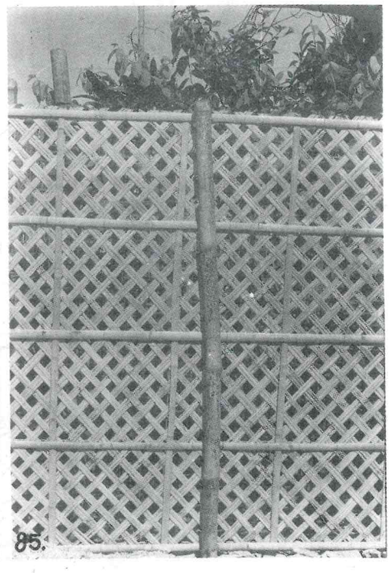

87.

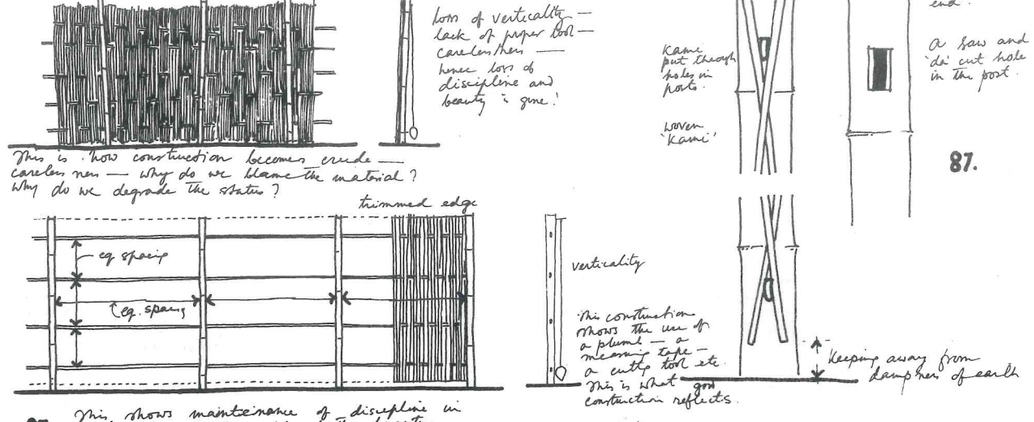
82. A HIGH COMPOUND FENCE. UNEQUAL LENGTHS AND SPACING — LOSS OF VERTICALITY — LESS CARE FOR DECENCY.
83. A HIGH COMPOUND FENCE. EQUAL LENGTHS OF WOVEN BAMBOOS — TRIMMED EDGE - EQUAL SPACING — A SIGN OF LITTLE CARE.
84. CLOSE VIEW OF THE FENCE IN 83. BLACKENING SHOWS THE WEATHERING OF THE MATERIAL. A LITTLE MORE EFFORT FOR THE REMOVAL OF THE STARCH CONTENT WOULD INCREASE THE LIFE.


83.


85.

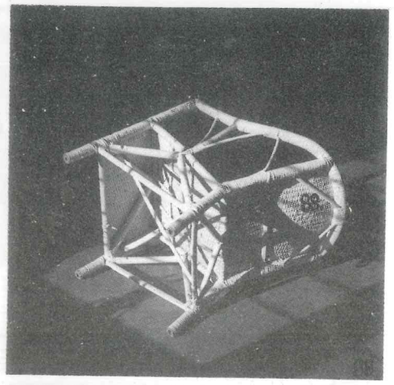
85. ANOTHER TYPE OF A HIGH FENCE — A DISCIPLINED CONSTRUCTION.
86. A BAMBOO 'JALI' OR GRILLE. A COATING OF PRESERVATIVE ADDS TO THE LIFE OF THE MATERIAL. WHEN USED UNDER COVER IT LASTS FOR 10 YEARS AND WITH PRESERVATIVE NOT LESS THAN 20 YEARS.
87. A HIGH COMPOUND FENCE. A FINE EXAMPLE OF DISCIPLINED CONSTRUCTION. DONE WITHOUT A SINGLE TIE OF ROPES OR WIRES.

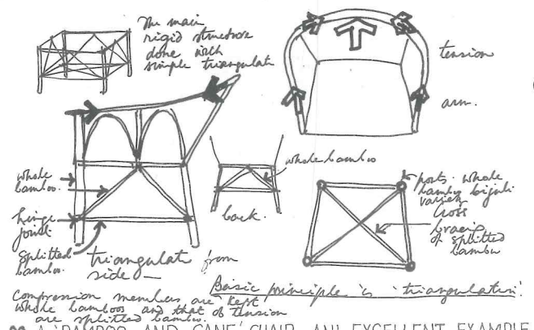
IT IS THE DISCIPLINE THAT MATTERS FOR BEAUTY OF CONSTRUCTION AND NOT THE MATERIAL ALONE.



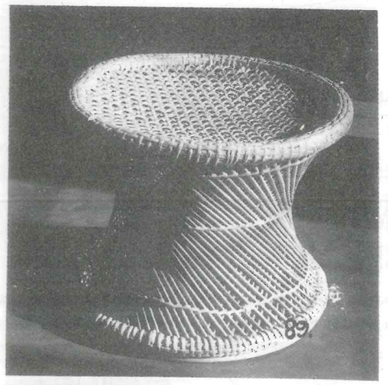
87. This shows maintenance of discipline in construction which adds to the beauty and dignity of the material. It does not cost extra expense but a little more care towards it.

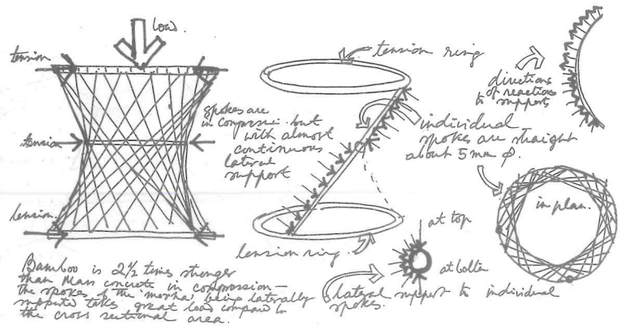
READING OF THE MATERIAL.
OBSERVATION : OBJECTS OTHER THAN HOUSES.



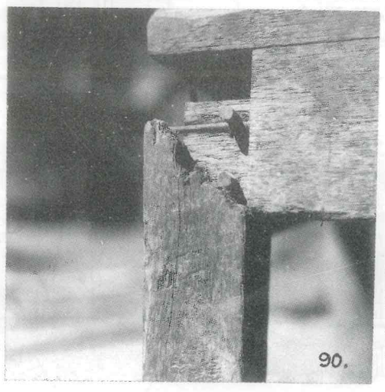


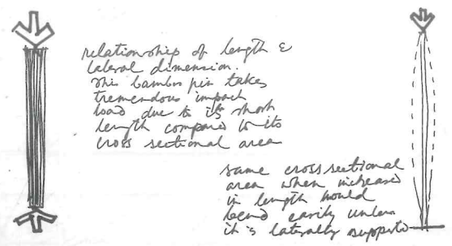
88. A 'BAMBOO AND CANE' CHAIR. AN EXCELLENT EXAMPLE OF A SOUND STRUCTURE TRUE TO THE MATERIAL.



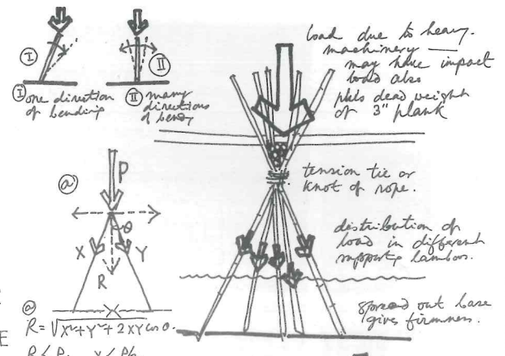


89. A 'MURHA' MADE OF BAMBOO SPOKES AND CANE. ANOTHER FINE EXAMPLE OF A SOUND STRUCTURE OF THE MATERIAL.

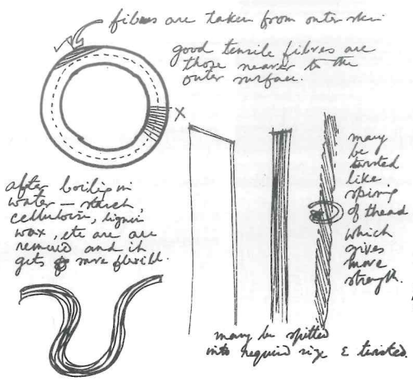




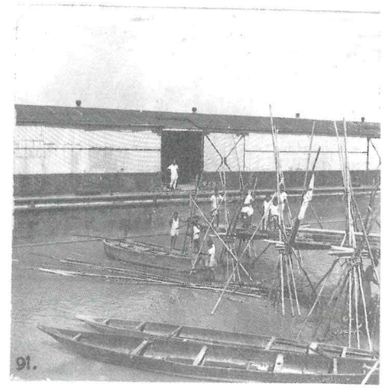
90. A BAMBOO PIN-FURNITURE JOINT. A FINE EXAMPLE OF ITS HIGH STRENGTH WEIGHT RATIO. ITS LONG FIBERS ARE STRONGER THAN TIMBER'S. A PIN FROM MATURED BAMBOO REMAINS IN TACT EVEN WHEN TIMBER FAILS.

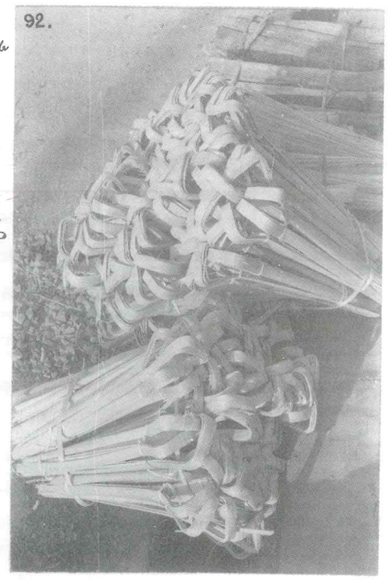


91. THIS BAMBOO AND 3" TIMBER PLANK BRIDGE ON RIVER BED TAKES HEAVY LOADS OF MACHINERIES AND OTHER GOODS FROM SHIP.



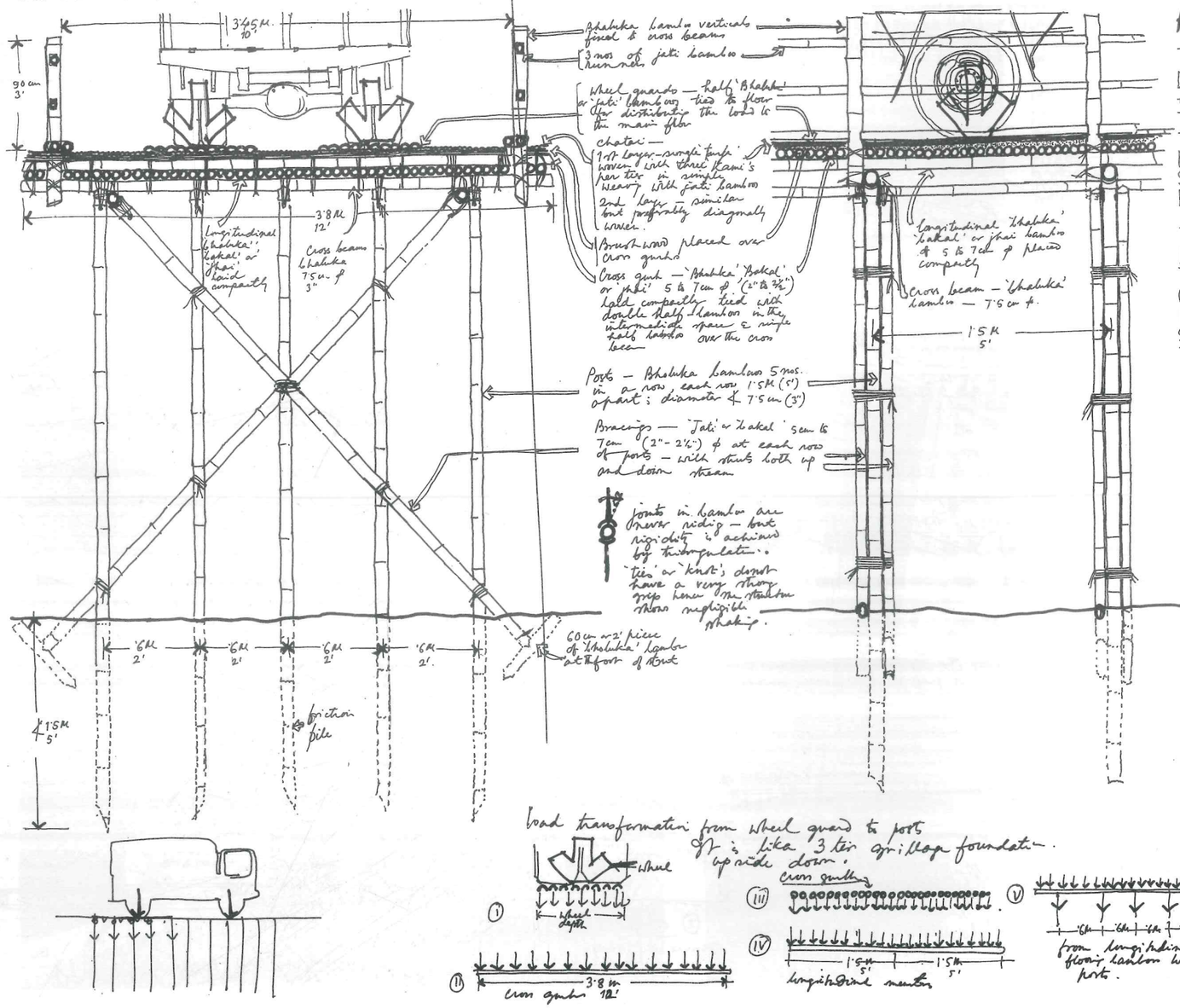
92. 'TAMAL' BOILED BAMBOO FIBRES. USED AS TYING ELEMENT IN BAMBOO CONSTRUCTIONS. SHOWS FLEXIBILITY OF BAMBOO





READING OF THE MATERIAL.

OBSERVATION : OBJECTS OTHER THAN HOUSES.



AN ALL-BAMBOO BRIDGE.

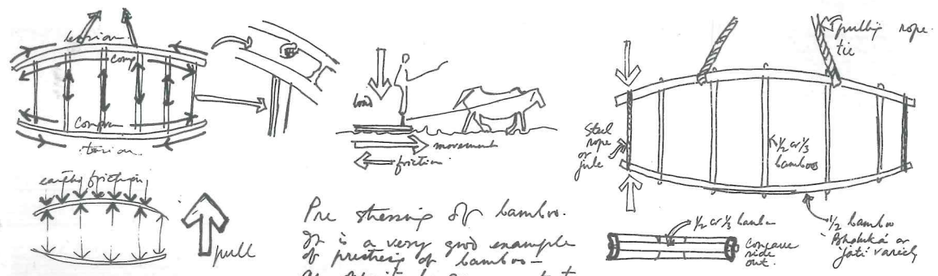
THIS IS GENERALLY DONE ON A SUB-WAY DIVERSION WHEN THE MAIN BRIDGE UNDERGOES REPAIR WORKS. IT TAKES ALL THE TRAFFIC LOADS WITH A LIMIT TO MAX 5 TONS (TONNE) IN SLOW SPEED. THIS BRIDGE HAS BEEN DESIGNED TO FUNCTION FOR SIX MONTHS ONLY. SO IT IS MENT FOR SIX MONTHS.

THE CONSTRUCTION IS DISCIPLINED AND REGULATED TOWARDS A SCIENTIFIC AND TECHNICAL WAY. KEEPING OF PLUMB, USE OF MEASURING TOOLS, ALIGNING OF DIFFERENT COMPONENTS ARE THE SIMPLE ELEMENTS TO SHOW ITS REGULATIONS IN CONSTRUCTION

READING OF THE MATERIAL.

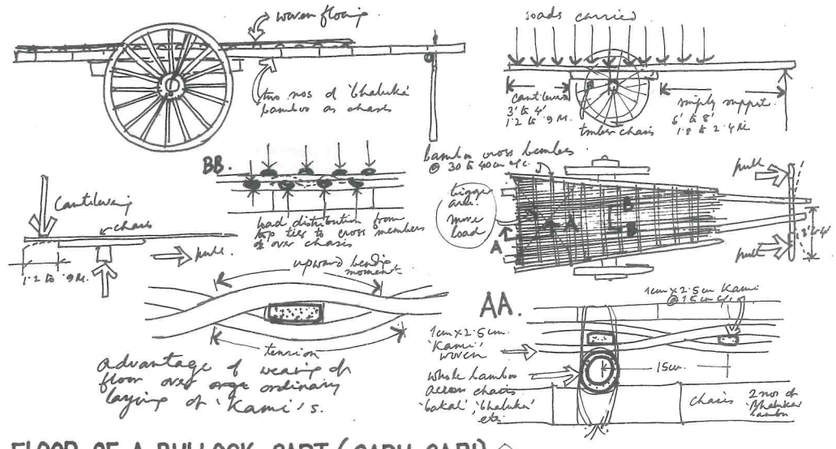
OBSERVATION : OBJECTS OTHER THAN HOUSES.

THESE OBSERVATIONS HAVE BEEN DONE WITH A VIEW TO KNOW THE BEHAVIOUR AND WORKING OF THE MATERIAL IN DIFFERENT FIELDS OF UTILITY.



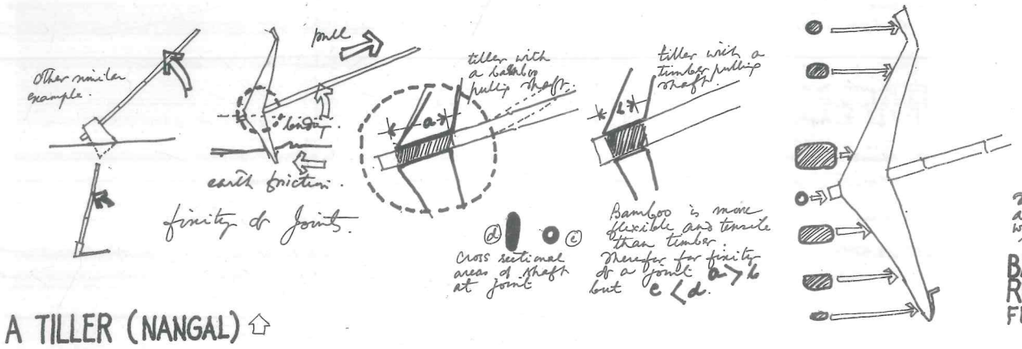
Pre stressing of bamboo. It is a very good example of prestress of bamboo. An opposite bending moment to the actual is given to the main member taking bending moment.

AN EARTH DRESSER (MOI)

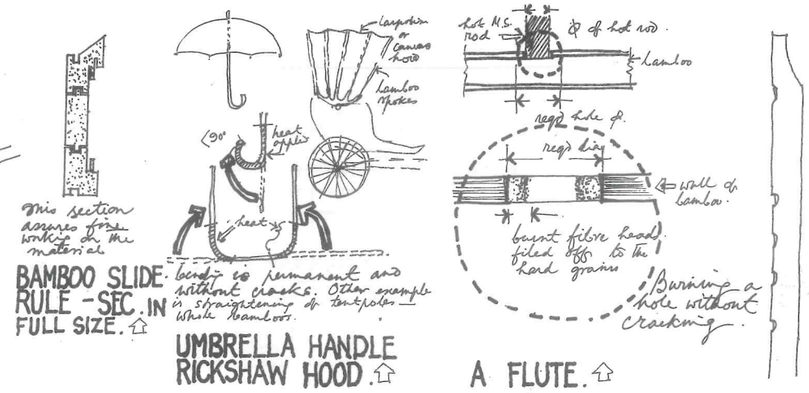


advantage of wearing of floor over ordinary laying of 'Kami's.

FLOOR OF A BULLOCK CART (GARU-GARI).



A TILLER (NANGAL)



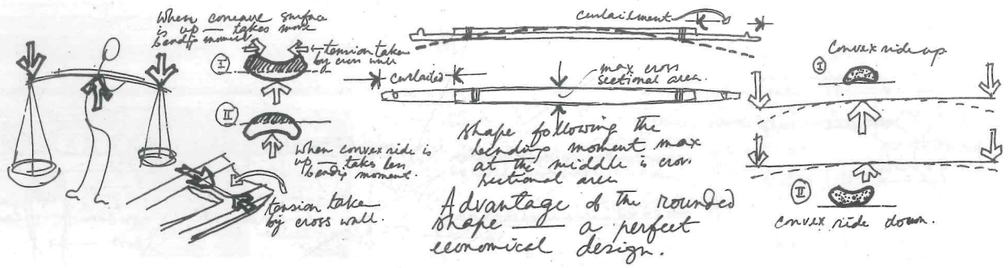
Mis section assures free working of the material

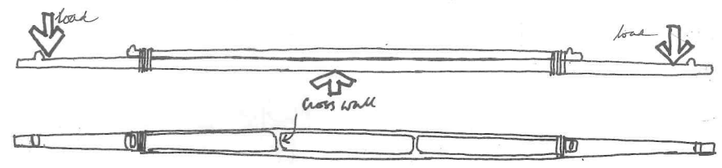
BAMBOO SLIDE RULE - SEC. IN FULL SIZE.

bending is permanent and without cracks. Other example is straightening of tent poles of whole bamboos.

UMBRELLA HANDLE RICKSHAW HOOD.

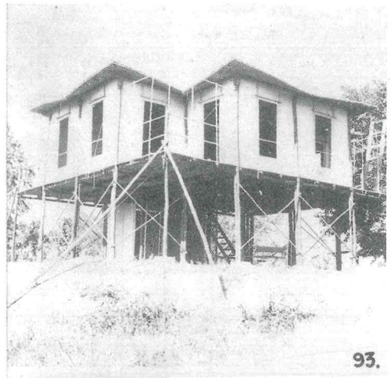
A FLUTE.





A CARRYING STICK (BAOKA OR BANKA).

READING OF THE MATERIAL.
OBSERVATION : A TIMBER-BAMBOO COMPOSITE HOUSE.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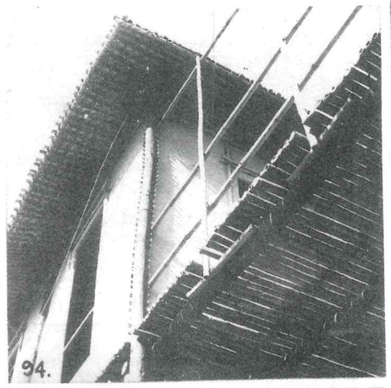
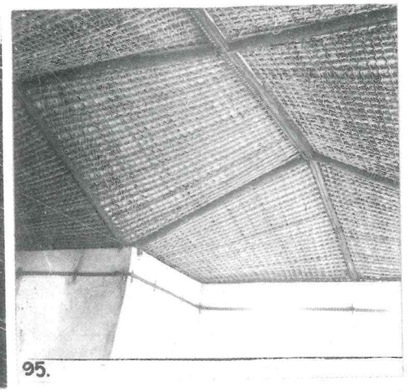
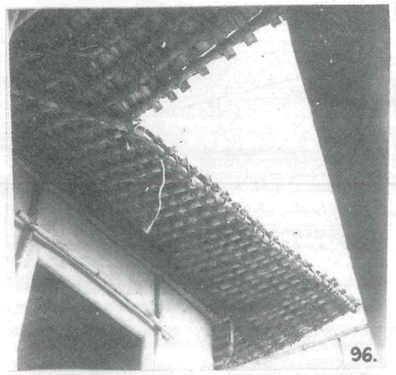

94.


95.

LOCATION – AHMEDABAD, GUJRAT. N.I.D. CAMPUS.
THIS HOUSE WAS INCOMPLETE WHEN THIS STUDY WAS DONE.
THE AIM WAS TO OBSERVE THE CONSTRUCTION SYSTEM IRRESPECTIVE OF THE PLANNIG.
POSTS – TIMBER.
ROOF STRUCTURE – TIMBER FRAME WITH NET WORK of HALF BAMBOOS
ROOFING MATERIAL –
FLOOR – BAMBOO ON TIMBER JOISTS, TOPPED WITH I.P.S.
DOORS AND WINDOWS. PLASTIC CLOTH FRAMED WITH STEEL TUBES.
WALL – BAMBOO REINFORCED CEMENT MORTAR.
HEIGHT – GROUND AND ONE UPPER FLOOR.
FOUNDATION – POSTS CLAMPED TO CONCRETE FOUNDATION
COST – ESTIMATED AT RS 8500·00 EXCLD. – SERVICES. RS 12·75/SQ FT.
LIFE – ?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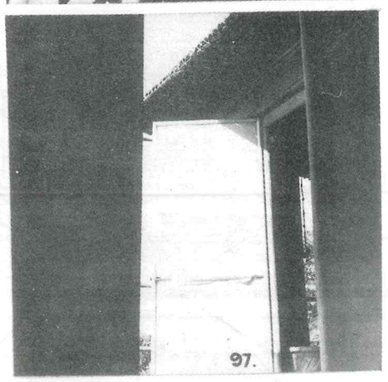
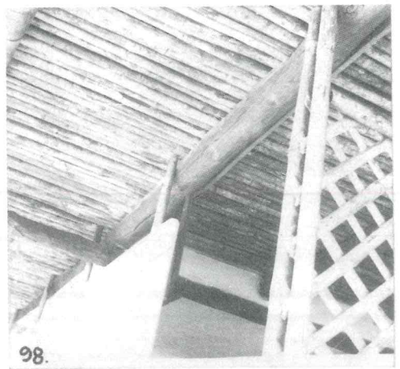
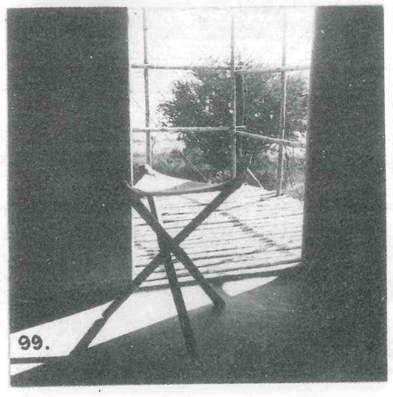

97.


98.

93 EXTERNAL VIEW OF THE HOUSE.
94 VIEWING FROM BELOW – ROOF AND FLOOR.
95 UNDERSIDE OF THE ROOF. A NETWORK OF HALF BAMBOOS TIED WITH ROPES.
96 ROOF EVE FROM BELOW.
97 DOOR OPENING, JAMB AND SHUTTER.
98 FIXING OF PARTITION TO FLOOR JOIST.
99 FINISHED FLOOR WITH A PARTIAL VIEW OF UNCOVERED FLOOR.
100 INSTALLATION OF COMODE ON BAMBOO FLOOR.
101 INSTALLATION OF WASH BASIN.
102 BAMBOO WALL WITH OPENING BEFORE PLASTERING.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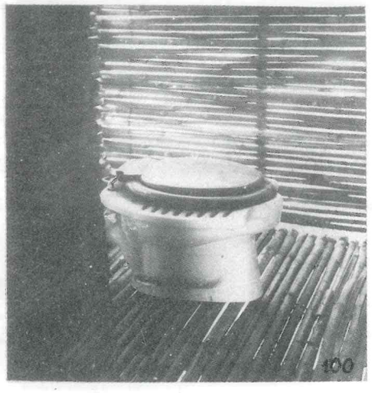
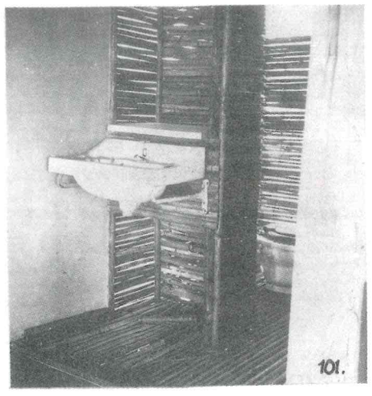

100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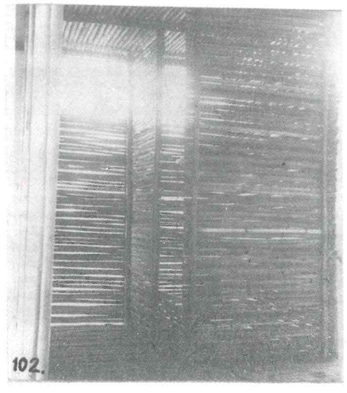
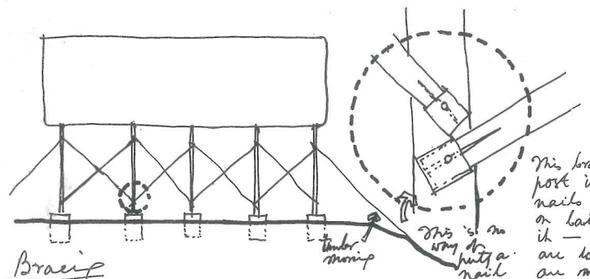

102.

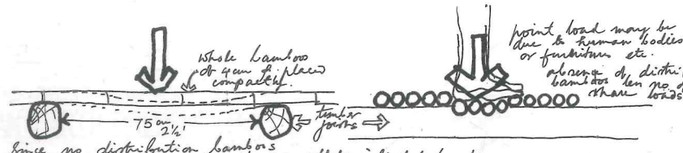
READING OF THE MATERIAL.
OBSERVATION : A TIMBER-BAMBOO COMPOSITE HOUSE.



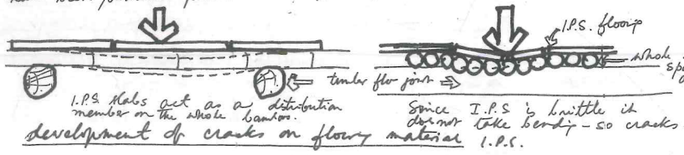
Bracing

Bracing done to resist the shakings of the building is not functioning. Extra timber bracings are added to the four corner.

This bracing of the post is a failure — nails put directly on bamboo splits it — steel caps are loose as they are made first and the bamboos put in are of varying diameters.

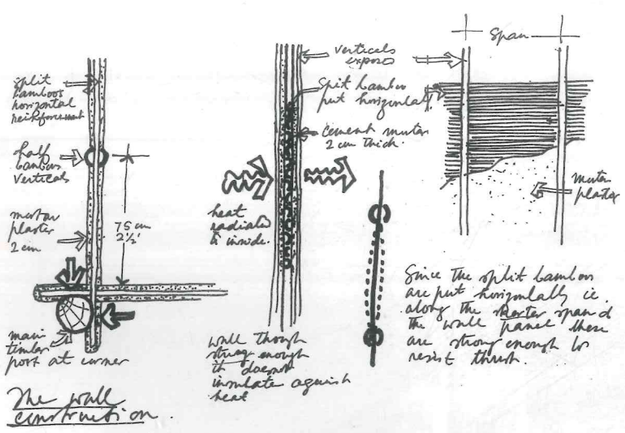


Since no distribution bamboos have been provided point loads effect individual bamboos.

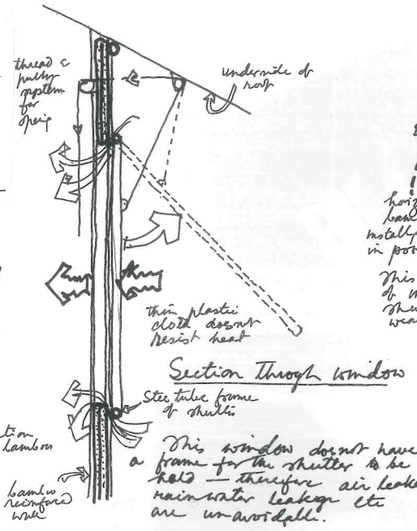


I.P.S. slabs act as a distribution member on the whole bamboo. development of cracks on floory material

Since I.P.S. is brittle it does not take bendy - so cracks I.P.S.

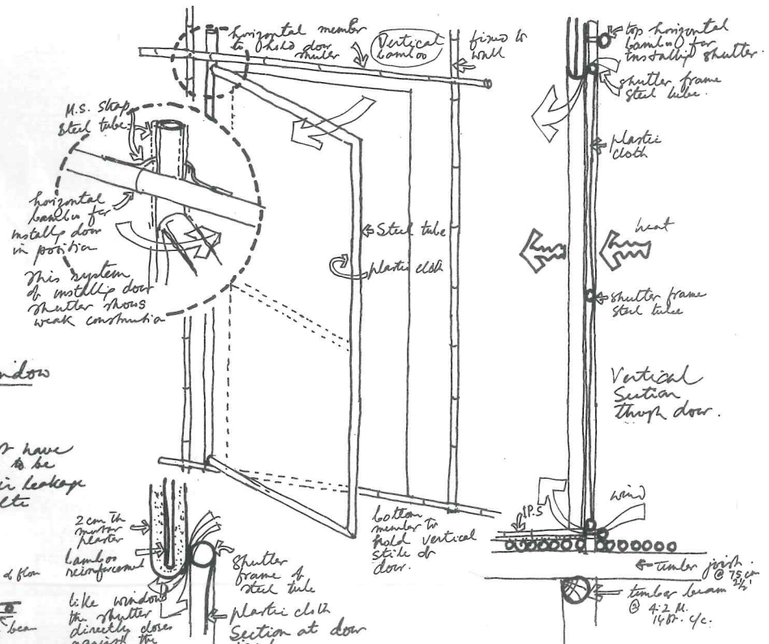


The wall construction.



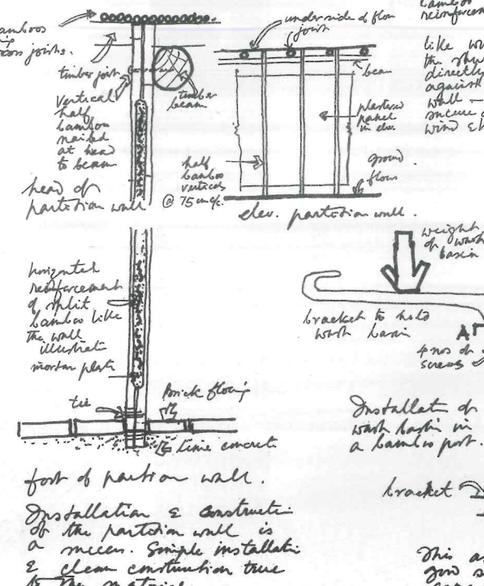
Section Through window

This window does not have a frame for the shutter to be held — therefore air leakage rainwater leakage etc are unavoidable.

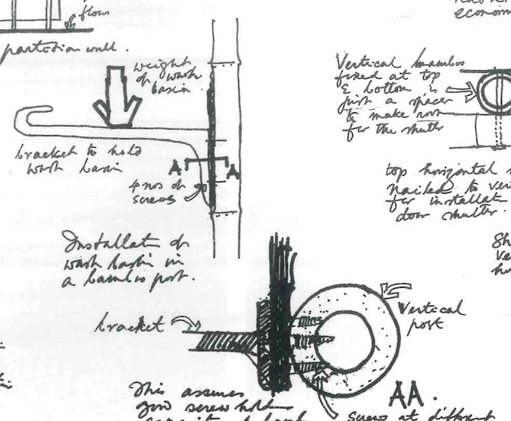


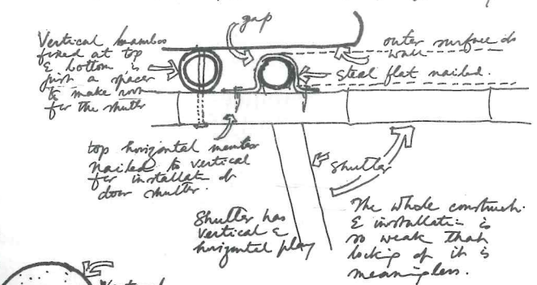
Like windows the shutter directly closes against the wall — does not secure against wind & rain

This door design of today is worse than the sliding door of yesterday (illustrated) Very very weak — it is like a tent door — no security & protection against natural calamities — This is not economy but lacking in efficiency

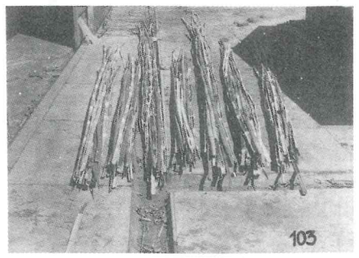


Installation & construction of the partition wall is a mixture. Simple installation & clean construction true to the material.

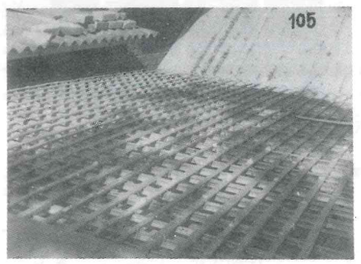




READING OF THE MATERIAL.
OBSERVATION : BAMBOO REINFORCEMENT IN CONCRETE.


103


104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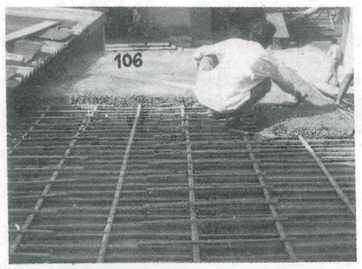
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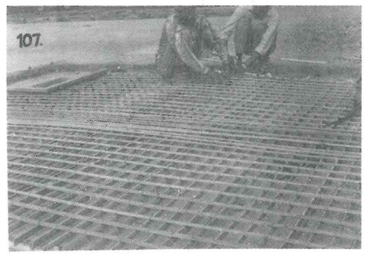
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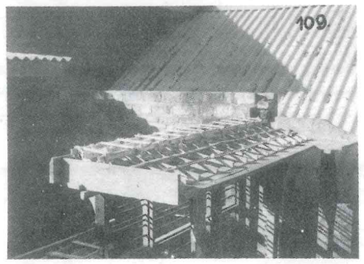
108.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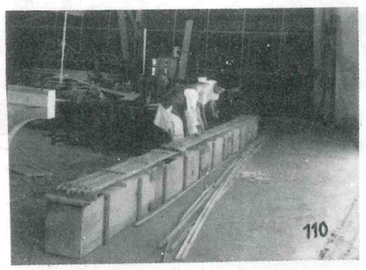
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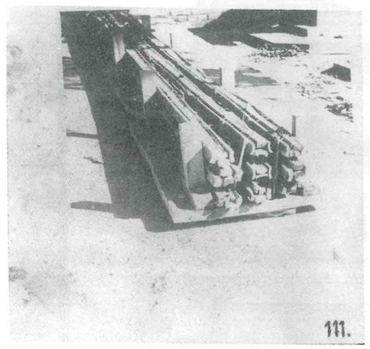
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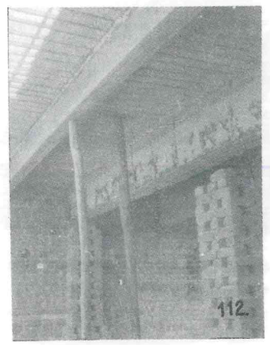

112.

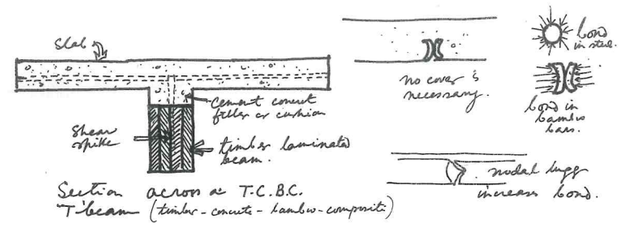
PHOTOGRAPHS.
103. TREATED STRIPS FOR REINFORCEMENT.
104. ARRANGEMENT OF REIINFORCEMENT ON GROUND (FOR ONE-WAY SLAB)
105. ARRANGEMENT OF REINFORCEMENT ON SITE FOR A TWO WAY SLAB.
106. LAYING OF CONCRETE. NOTE THE BAR S ABOVE BEAM FOR NEGATIVE BENDING.
107. TYING ON SITE.
108. FINISHED SLAB.
109. REINFORCEMENT FOR A SUN-SHED.
110. A PRECAST LINTOL.
111. A PRECAST ELECTRIC POLE.
112. T.C.B.C. T BEAM SEEN FROM BELOW. NOTE THE UNCOVERED REINFORCING BAMBOO STRIPS.

DESCRIPTION.
BAMBOO REINFORCEMENT WAS FIRST USED IN CHINA IN 1919 BY THE "SZECHUAN HANKOW RAILWAY" IN CONCRETE PILES. A 50% SAVING IN COST — FROM DOLLAR 28 TO DOLLAR 14 PER MILE WAS DONE. BAMBOO REINFORCED CONCRETE WAS NEXT USED FOR BUILDING ROADS AND IN A HOSPITAL FLOOR AT CANTON IN CHINA. IN INDIA MR. N.J. MASANI OF F.R.I. HAD INITIATED BAMBOO AS REINFORCEMENT FOR CULVERTS UPTO 4 M. SPAN ON ASSAM GRAND TRUNK ROAD DURING 1943 II WORLD WAR PERIOD RESEARCH WORK IS BEING CARRIED OUT FOR LAST FOUR YEARS IN F.R.I. DEHRADUN.

LASTING PERIOD. 60 YEARS AND ABOVE FOR CHEMICALLY TREATED BAMBOO AND 20 YEARS AND ABOVE FOR UNTREATED BAMBOO

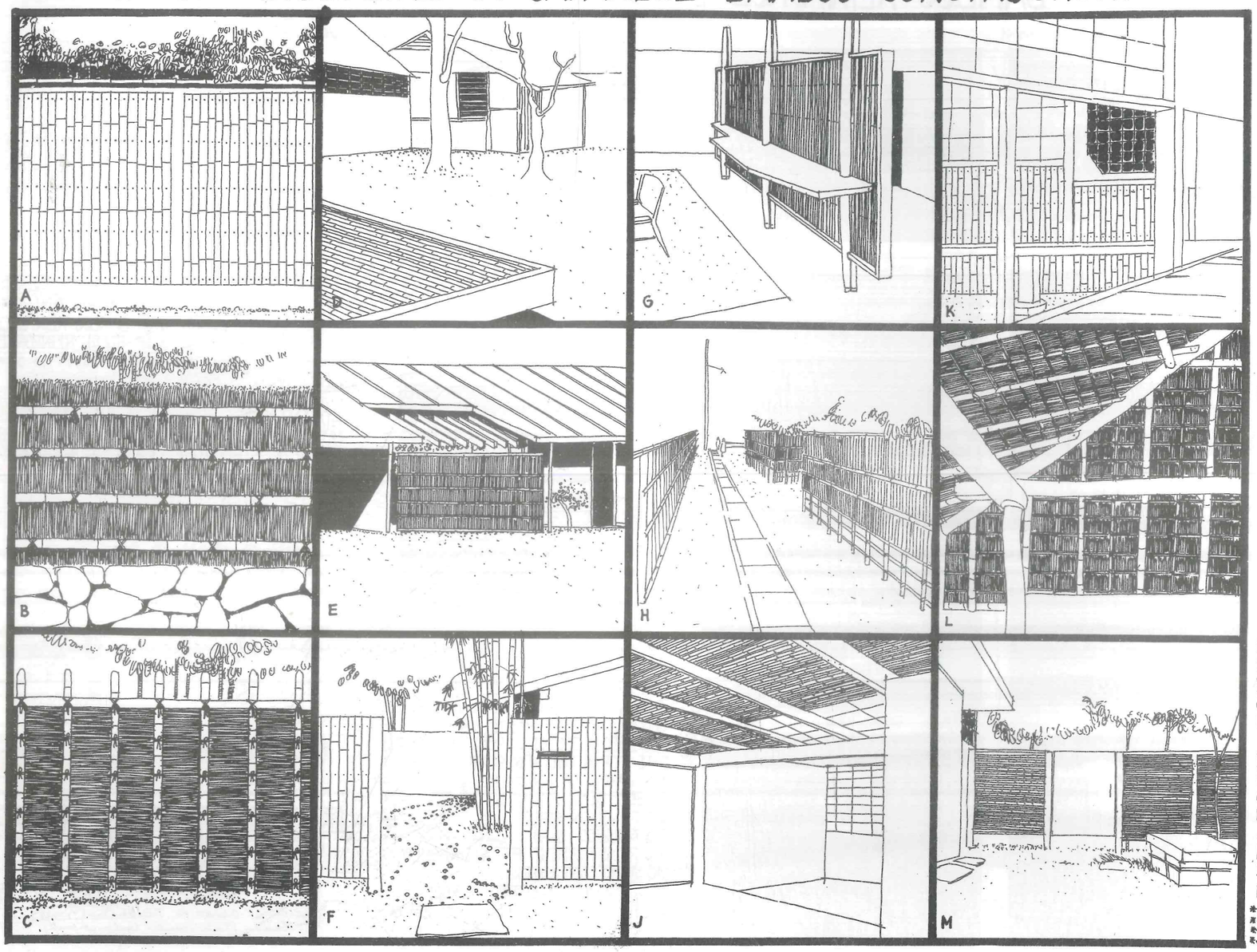
ECONOMY. BAMBOO REINFORCED CEMENT CONSTRUCTION IS 33% CHEAPER THAN STEEL R.C.C. CONSTRUCTION. TIMBER-CONCRETE-COMPOSITE CONSTRUCTION WITH BAMBOO REINFORCEMENT IN FLANGE IS 28% CHEAPER THAN WITH STEEL REINFORCEMENT. BAMBOO REINFORCED CEMENT CONCRETE 'T' BEAM IS 30·4% CHEAPER THAN STEEL R.C.C. 'T' BEAM.

ADVANTAGES. ECONOMICAL, NOT ATTACKED BY LIME CONCRETE, NO COVER IS NEEDED TO REINFORCEMENT, POSSIBILITY OF ANTI-MAGNETIC STRUCTURE; CHEAPLY AVAILABLE.



Section across a T.C.B.C. T-beam (timber-concrete-bamboo-composite)

READING OF THE MATERIAL.
OBSERVATION : DISCIPLINE IN JAPANESE BAMBOO CONSTRUCTION.



A FEW GLANCES.

SIMPLE DISCIPLINE AND ORDER IN CONSTRUCTION ADDS TO THE BEAUTY AND STATUS OF A MATERIAL WITHOUT COSTING ANY EXTRA EXPENSE. A LITTLE SYMPATHY TOWARDS THE MATERIAL AND WITH PROPER TOOLS FOR ITS SHAPING THE DISCIPLINE MAY BE ACHIEVED WHICH IS LACKING IN THE BAMBOO-BUILDING CONSTRUCTION OF ASSAM.

THESE GLANCES ON JAPANESE WAY OF BAMBOO CONSTRUCTION REVEALS ORDER AND DIGNITY, AND THE SYMPATHY TOWARDS THE MATERIAL.

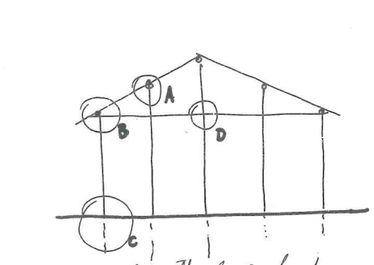
SKETCHES.

A. HIGH COMPOUND WALL.
B. GARDEN FENCE.
C. HIGH COMPOUND WALL.
D. TIMBER FRAMED BAMBOO FLOOR.
E. GARDEN WALL.
F. COMPOUND WALL.
G. PARTITION WALL.
H. COMPOUND WALL.
J. BAMBOO CEILING.
K. EXTERIOR-WALL PANELS.
L. ROOF FROM BELOW.
M. COMPOUND WALL.

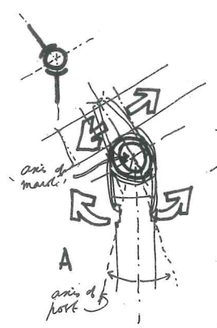
* REFERENCES.
*JAPANESE TEMPLES AND TEA HOUSES.
*JAPANESE HOUSES TO-DAY.
*JAPAN ARCHITECT 101.
*JAPANESE HOUSE.

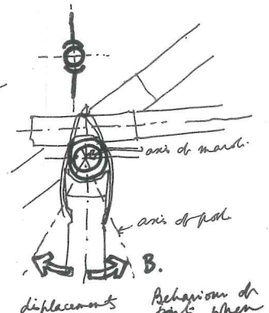
READING OF THE MATERIAL.
OBSERVATION : BEHAVIOUR OF A BAMBOO HOUSE IN EARTH TREMOR.

A BAMBOO HOUSE BEHAVES IN A VERY PECULIAR WAY DURING EARTH TREMOR. DUE TO THE LOOSE FLEXIBLE JOINTS IN THE STRUCTURE AND TOP-HEAVY CONSTRUCTION THE HOUSE BEHAVES AS ILLUSTRATED. IT IS SEEN, FROM STATISTICAL DATA, THAT GENERALLY A BAMBOO HOUSE RETAINS IT'S SHAPE DURING EARTH TREMOR WHILE OTHER BRICK AND CONCRETE STRUCTURES ARE AFFECTED.



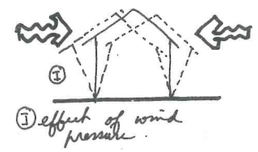
cross section through a bamboo house — as illustrated earlier all the joints are loose and flexible.





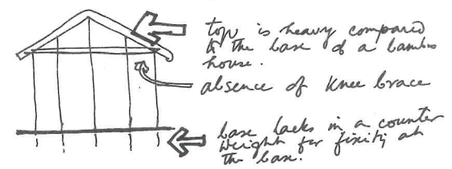
displacement exaggerated.

Behaviour of joints when shaking take place across the longitudinal axis.



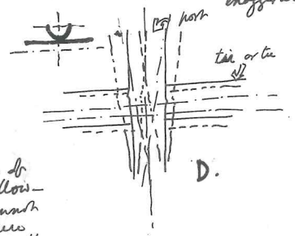
(I) effect of wind pressure.

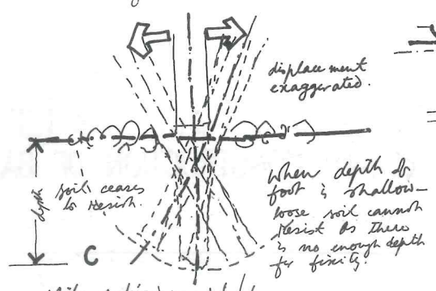
(II) effect of earth tremor.

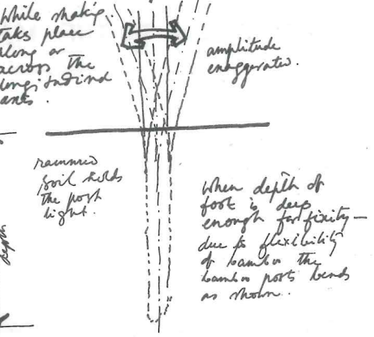

top is heavy compared to the base of a bamboo house.

absence of knee brace

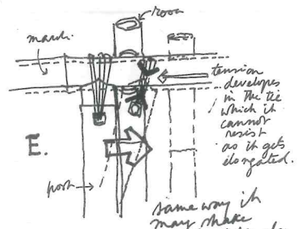
base lacks in a counter weight for fixity at the base.





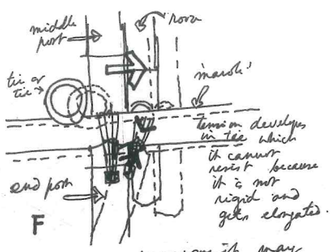


Section along the longaxis behaviour of joints in longitudinal shaking is illustrated.



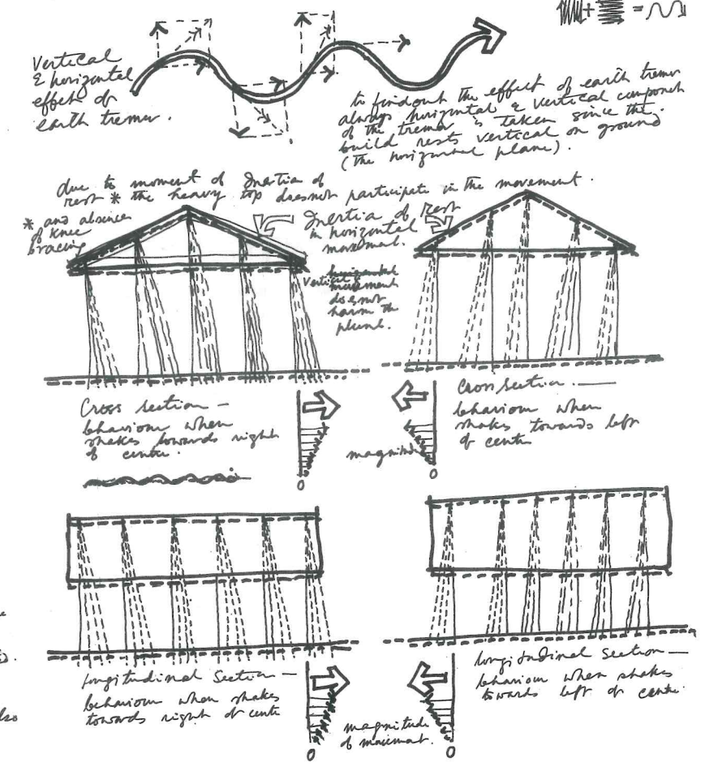
tension developes in the tie which it cannot resist as it gets elongated.

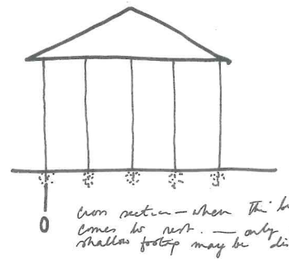
same way it may shake towards left also



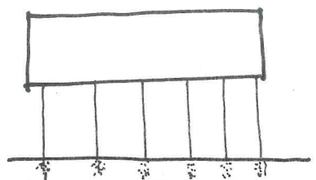
tension developes in the tie which it cannot resist because it is not rigid and gets elongated.

same way it may shake towards left also





cross section — when the building comes to rest. — only the shallow footing may be disturbed.



long section — when the building come to rest — only the shallow footing may be disturbed unlike deep footing — this may be removed to lightness.

READING OF THE MATERIAL.
CONCLUSIONS DRAWN.

1. BAMBOO IS AS OLD AS TIMBER IN NATURE AND IS NOT BEEN FULLY EXPLOITED.
2. FASCINATION TOWARDS NEW MATERIALS, LIKE BRICKS, CONCRETE, STEEL ETC PARALISED THE EXPLOITATION.
3. BAMBOOS OF ASSAM COVER ALMOST ALL THE VARIETIES OF INDIAN BAMBOOS AND IS THE LARGEST RESERVE IN INDIA.
4. BAMBOOS HAVE GOT ALL THE PROPERTIES OF A GOOD STRUCTURAL MATERIAL WITH ITS OWN STRESS MORPHOLOGY.
5. PRESENT BAMBOO BUILDING CONSTRUCTION IS CARELESS AND NEGLECTED.
6. ABSENCE OF PROPER TOOLS FOR SHAPING RESULTED IN THE CRUDENESS OF PRESENT CONSTRUCTION OF BAMBOO.
7. BAMBOO IS AN IDEAL MATERIAL OF CONSTRUCTION FOR SEISMIC ZONE.
8. WASTEFUL CONVERSION PRACTICE OF BAMBOO NEEDS A REFORMATION. A TRUE THOUGHT GIVEN TO THE MATERIAL MAY SHOW A NOVEL WAY TO THE FIELD OF BUILDING CONSTRUCTION.

PART TWO

DERIVATION OF THE SYSTEM.

CONTENTS.

A SYSTEM OF BUILDING CONSTRUCTION WITH BAMBOO AS THE PRINCIPAL MATERIAL

DERIVATION OF THE SYSTEM.

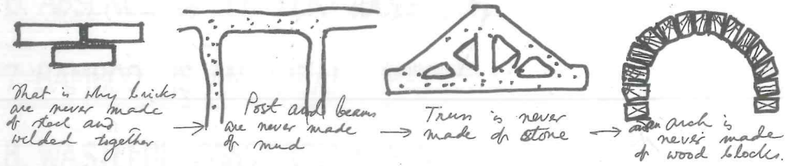
SCOPE

THE CONCLUSIONS DRAWN FROM THE **READING OF THE MATERIAL** HINTS AT THE VAST SCOPE OF BAMBOO BECOMING A **GOOD MEDIUM OF BUILDING CONSTRUCTION**. THE MATERIAL HAS EVERY REASON FOR EXISTENCE. IT HAS THE **CAPACITIES TO BEAR AND RESIST** WHILE INDULGED IN SHELTERING MAN. IT HAS A DEFINITE **STRESS MORPHOLOGY**, OF ITS OWN, TO BE CONSIDERED. IN ADDITION, ITS **LARGE AVAILABILITY** AND **LASTING PERIOD** MAKE IT FEASIBLE TO HAVE A SYSTEM OF BUILDING CONSTRUCTION WITH THIS MEDIUM.

WHAT SHAPES A BUILDING.

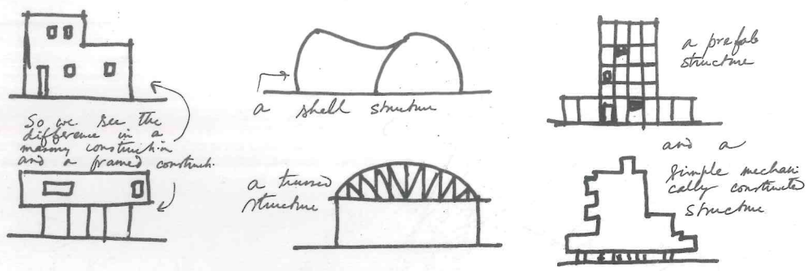
BASIC CONCEPT, AS EVERYBODY WOULD SAY, OF A BUILDING IS TO ENCLOSE A SPACE AND SHELTER FROM NATURAL CALAMITIES. BUT, **ALL THE STRUCTURES OF BUILDING, THOUGH BASED ON THE SAME CONCEPT, ON THIS EARTH ARE NOT ALIKE.** THE WHY IS THAT THEY HAVE CERTAIN GUIDING FACTORS WHICH SHAPE THEM.

MEDIUM OF CONSTRUCTION CHANGES THE STRUCTURE.



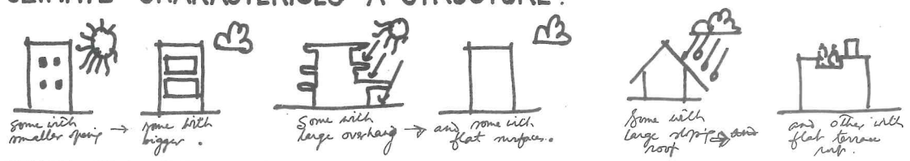
HENCE A BAMBOO STRUCTURE WILL HAVE ITS OWN SYSTEM OF CONSTRUCTION.

METHOD OF CONSTRUCTION SHAPES THE STRUCTURE



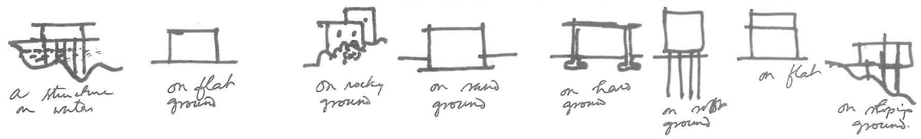
HENCE A BAMBOO STRUCTURE WILL HAVE ITS OWN APPEARANCE.

CLIMATE CHARACTERISES A STRUCTURE.



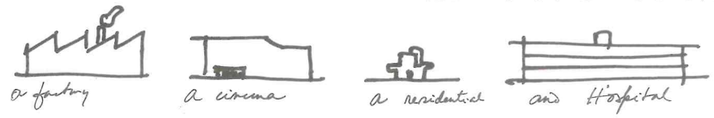
HENCE THE STRUCTURE SHALL FOLLOW THE CLIMATE OF ASSAM.

SITE CONSIDERATIONS GIVE THE BASE TO THE STRUCTURE.



HENCE PLAIN AND HILLY SITE SHALL GUIDE THE STRUCTURE.

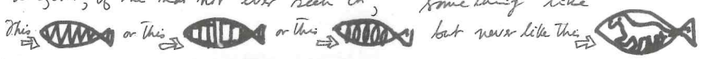
FUNCTION CHANGES THE SCALE OF A STRUCTURE.



SINCE THE FOLLOWING SYSTEM OF CONSTRUCTION IS FOR RESIDENTIAL BUILDINGS IT WILL HAVE THE SCALE SUITABLE FOR THE SAME.

AESTHETICAL CONSIDERATION TO A STRUCTURE.

Aesthetical considerations take place in the visible parts of the structures. Now, should the external appearance of a building forcibly convince us of the internal phenomena?
Externally skeleton of a building may or may not be seen but the total form always gives a hint to the internal structure. That is why a person able to perceive a structure behind a form, would perceive the skeleton of a fish, if he has not ever seen it, something like



HENCE EXTERNAL APPEARANCE SHALL NOT DECEIVE OF INTERNAL PHENOMENA.

INDUSTRIAL AND ECONOMICAL STANDARD GUIDE A STRUCTURE.

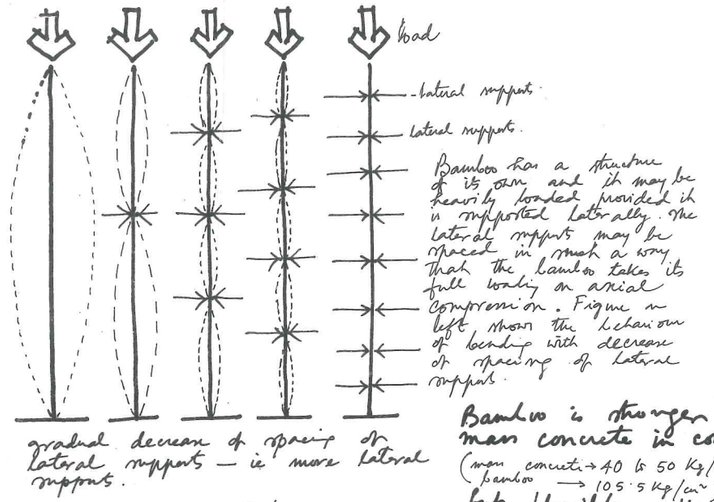
ASSAM IS ECONOMICALLY BACKWARD AND INDUSTRIALLY NOT ADVANCED. **HENCE THE STRUCTURE SHALL BASE ON SIMPLE MECHANICAL METHOD AND ECONOMY.**

A SYSTEM OF BUILDING CONSTRUCTION WITH BAMBOO AS THE PRINCIPAL MATERIAL.

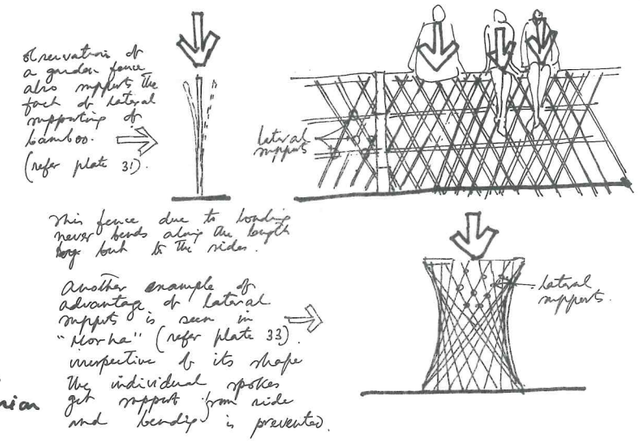
DERIVATION OF THE SYSTEM.

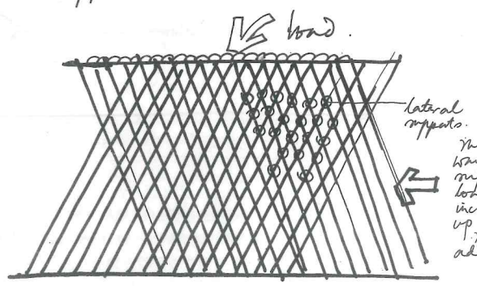
CONCEPT

LOADING AND LATERAL SUPPORT ⇩



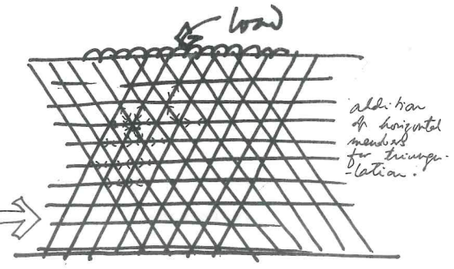
Bamboo is stronger than mass concrete in compression (mass concrete → 40 to 50 Kg/cm². bamboo → 105·5 Kg/cm²) but flexible. Hence by proper lateral support the advantage of compressive strength may be taken.



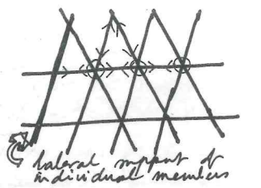


Therefore the simplest way to have lateral supports is to keep the load bearing members inclined and tie them up to one another. This is done without additional members.

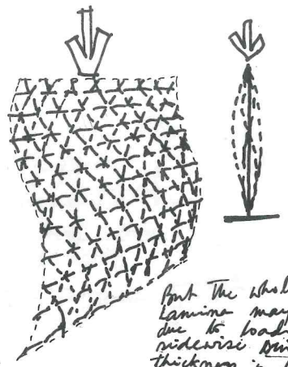
rigid joints in bamboo are not possible unless extra rigid material is used in the joints. rigidity may be achieved by simple triangulation.



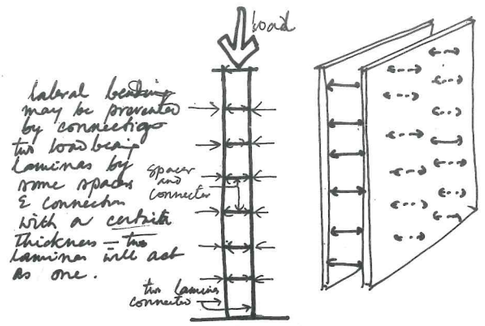
DERIVED LOAD-BEARING COMPONENT ⇩



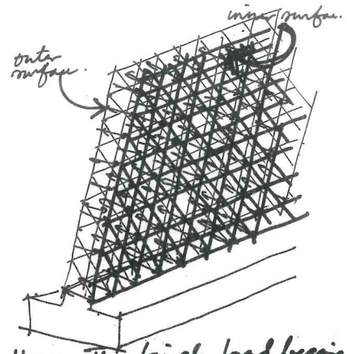
Now the whole thing becomes a lamina where individual members are supported laterally to one another in the direction of the length. Therefore the members will not bend along the length.



But the whole lamina may bend, due to loading on sidewise direction the thickness is less and no lateral support.



Connection to the load bearing laminas for rigidity.

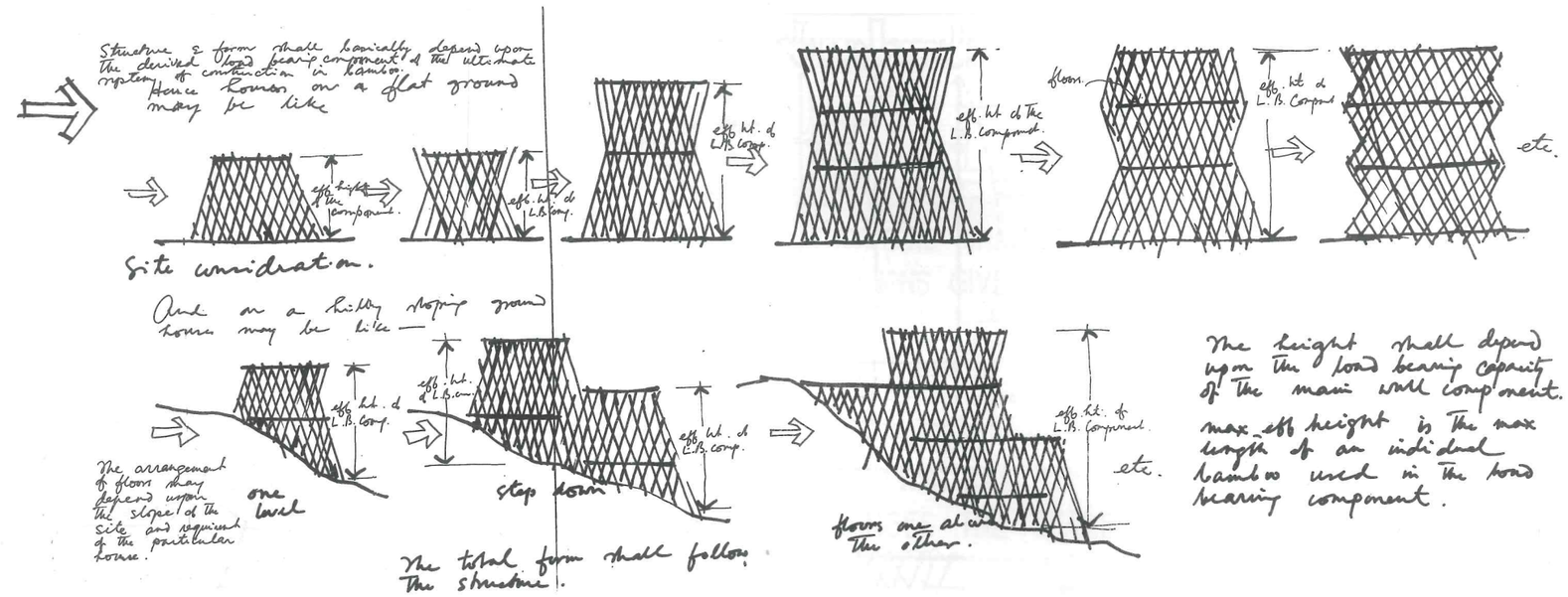


Hence the final load bearing component of the system may be like as shown above.

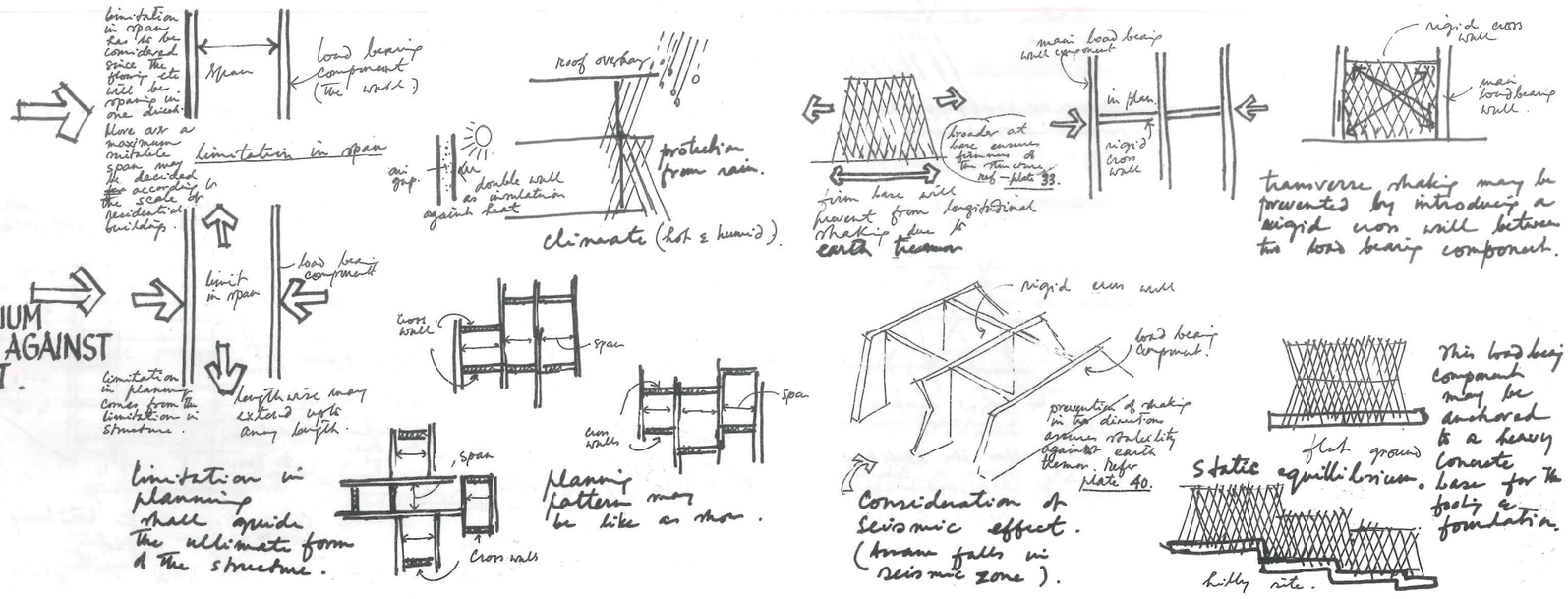
DERIVATION OF THE SYSTEM.

CONCEPT.

STRUCTURE FORM AND SITE



PLANNING PATTERN

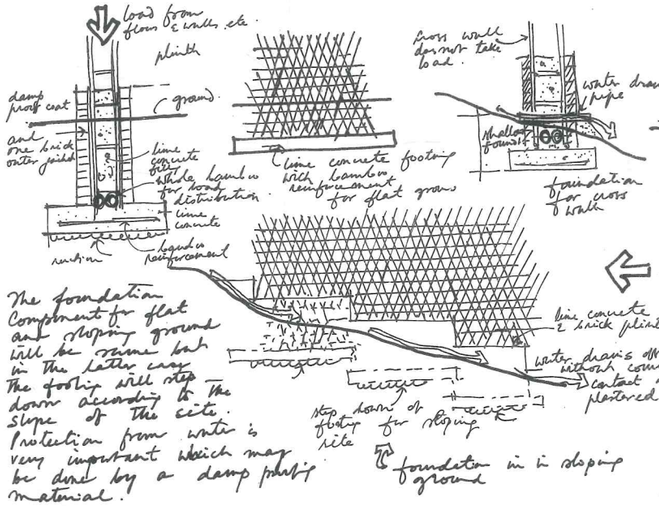


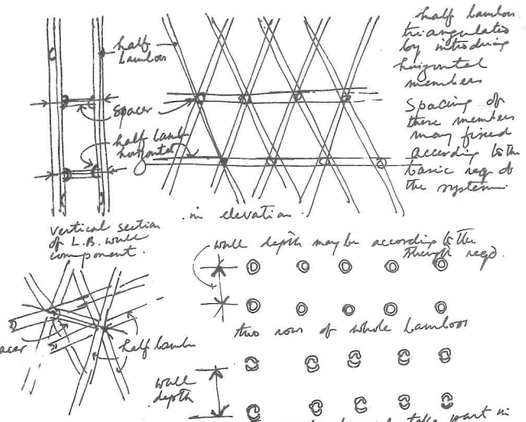
A SYSTEM OF BUILDING CONSTRUCTION WITH BAMBOO AS THE PRINCIPAL MATERIAL.

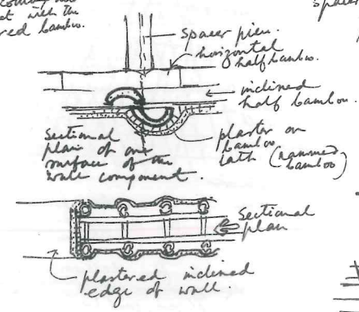
DERIVATION OF THE SYSTEM.

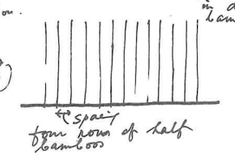
CONCEPT.

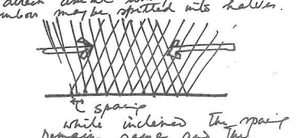
FOUNDATION COMPONENT





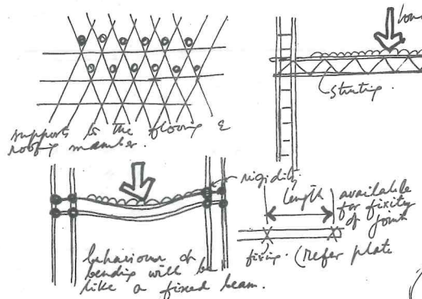


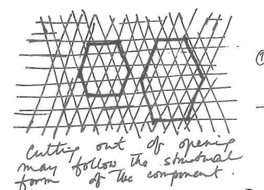


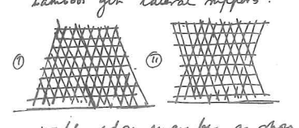


LOADBEARING WALL COMPONENT

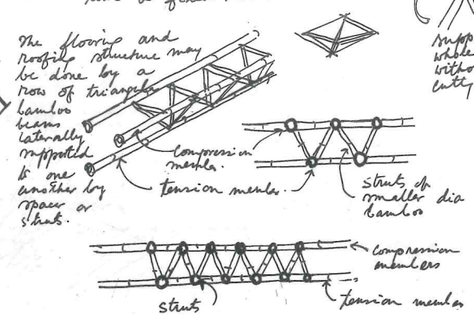
PARTITION WALL COMPONENT

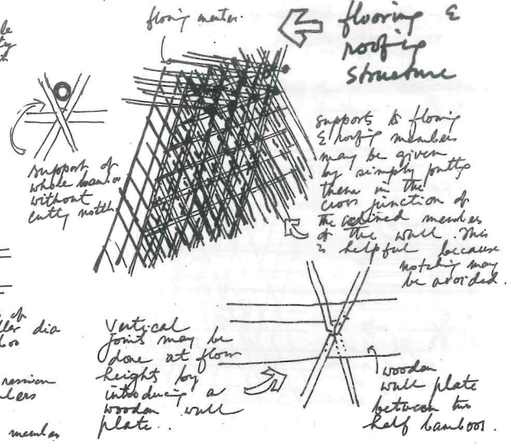


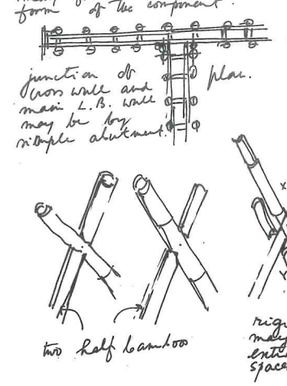


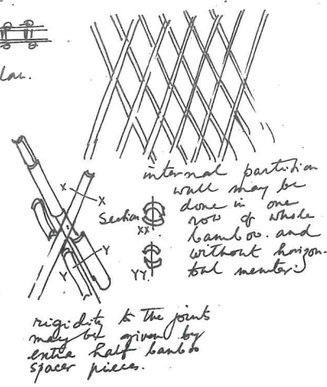


FLOOR & ROOF SUPPORTING COMPONENT.









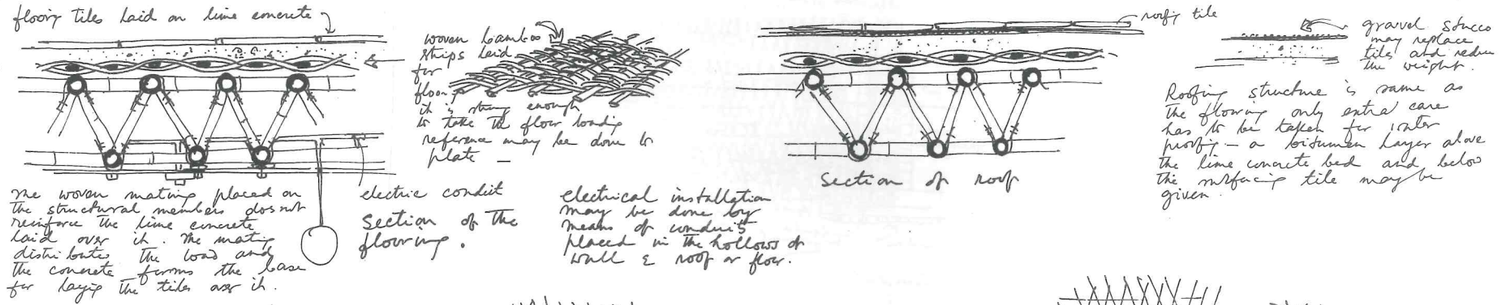
A SYSTEM OF BUILDING CONSTRUCTION WITH BAMBOO AS THE PRINCIPAL MATERIAL.

DERIVATION OF THE SYSTEM.

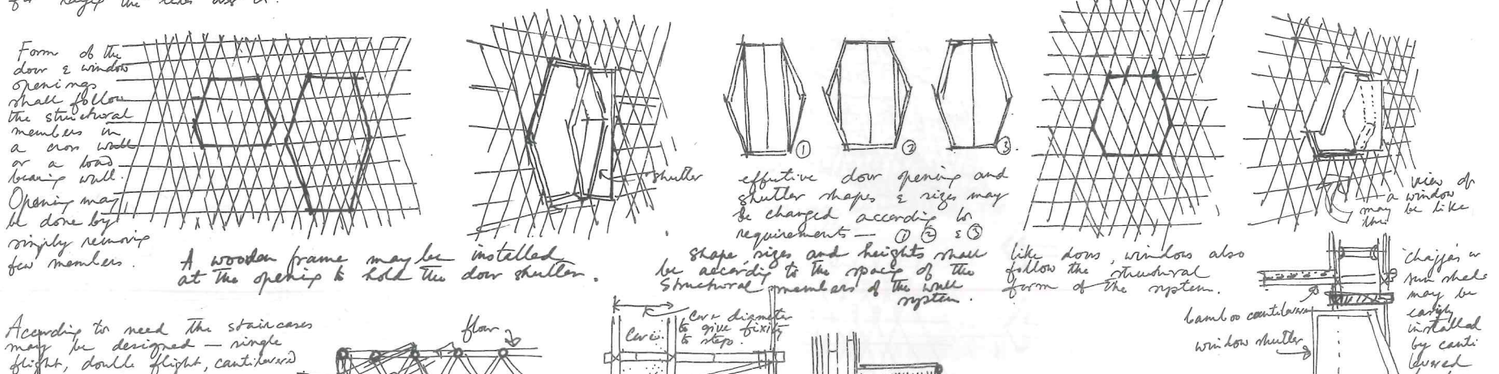
CONCEPT.

FLOOR & ROOF COMPONENTS.

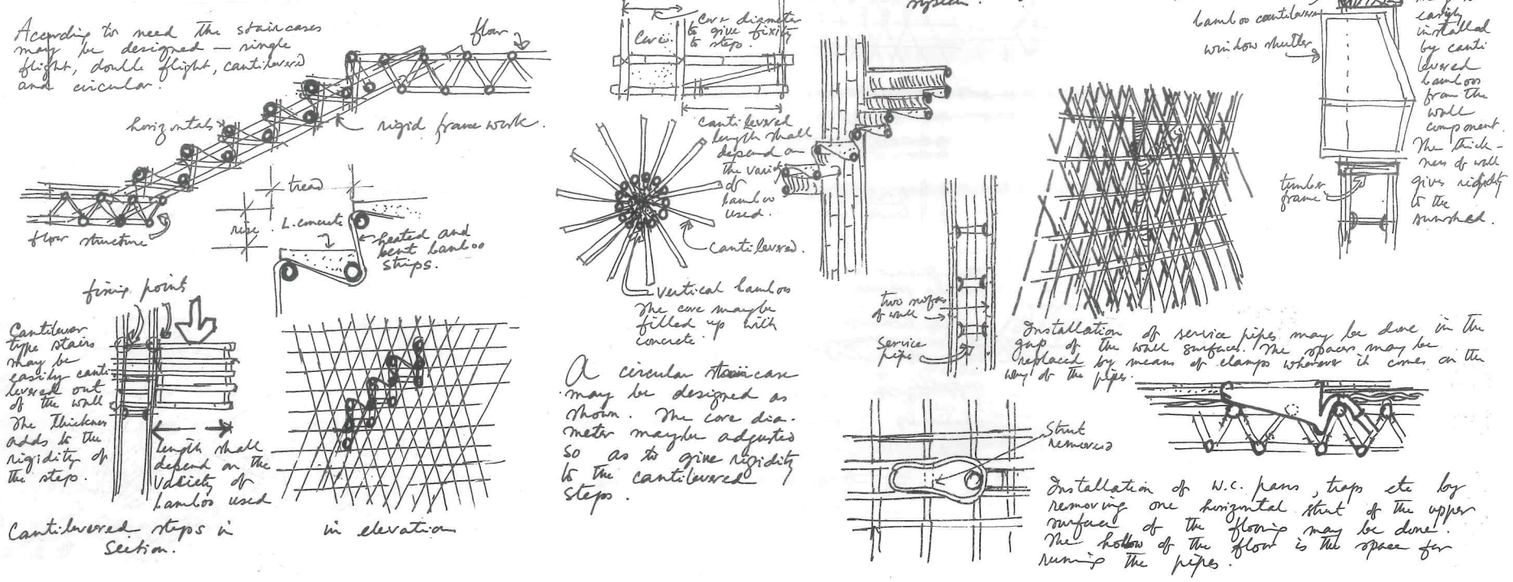
ELECTRIC INSTALLATION.



DOORS AND WINDOW COMPONENTS.



STAIR CASE COMPONENT.



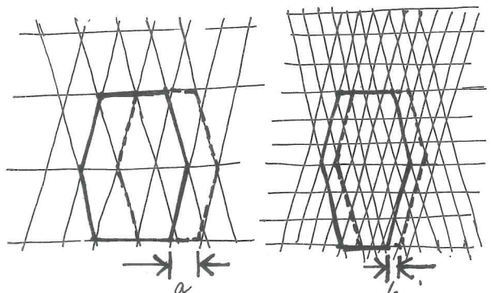
SERVICE PIPE ETC INSTALLATION.

DERIVATION OF THE SYSTEM.
BASIC STRUCTURE.

OWING TO THE PRACTICAL LIMITATIONS FOR ACTUAL EXPERIMENTS THE SYSTEM HAS BEEN WORKED OUT BY MATHEMATICAL CALCULATIONS BASED ON TECHNICAL DATA AND SIMPLE STATICS, JUSTIFICATIONS AND REASONINGS AND ON OBSERVATIONS DONE.

FIXING OF SPACING AND INCLINATION OF BAMBOOS IN THE MAIN LOAD BEARING COMPONENT.

Spacing →

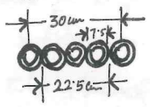


Close spacing of bamboos gives more flexibility of planning. In the fig 'b' is smaller than 'a' i.e the horizontal module for cutting out of door & window openings etc are more flexible in case of 'b'. Therefore there will be more variations of door positioning in case of 'b'.
but too close spacing will be uneconomical — wastage of material & too many joints.

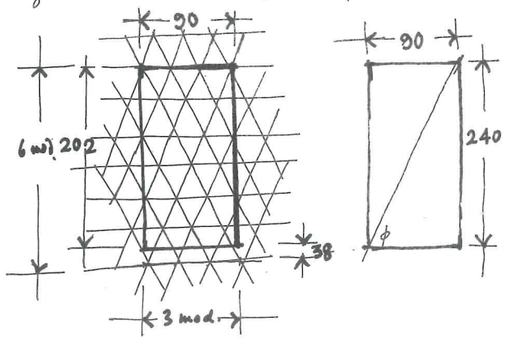
Now considering flexibility of spacing & economy Spacing selected is 30 cm. which is based on the module of 7·5 cm → the average diameter of a 'bholuka' bamboo.

7·5 X 4 → 30 cm.

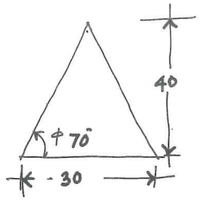
Now, a gap between two bamboos may be filled up with three nos of bamboos.



Inclination → The inclination shall depend upon the vertical module of bamboos and this in turn is related to the doors and window openings. Thus the spacing is selected in such a way that the final door opening becomes the conventional door size of a residential building



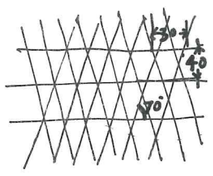
width → 3 horizontal division 30 X 3 → 90 cm.
Height → conventional door height + floor thickness
200 + 38 → 238 cm.



for roundly six divisions —
6 X 40 → 240 cm.
∴ clear height → 202 cm.

tan ϕ → 240/90 = 8/3 = 2·67.
ϕ → 69°30′ ≃ 70°

∴ Horizontal module → 30
Vertical module → 40
Angle of inclination → 70°



DERIVATION OF THE SYSTEM.
BASIC STRUCTURE.

LOAD BEARING CAPACITY OF THE MAIN STRUCTURAL WALL COMPONENT.

THE COMPONENT SHOULD STAND THE WORST CONDITION OF LOADING. HENCE THE CAPACITY SHOULD BE CHECKED FOR THE POSITION WHEN IT IS IN GROUND FLOOR AND COMMON TO TWO FLOORS WITH MAXIMUM SPANNING AND DOUBLE FLOOR HEIGHT.

Load bearing Capacity of one 'bholuka' bamboo

The average cross sectional area of one 'bholuka' bamboo

$\rightarrow \pi r_1^2 - \pi r_2^2$

$= \pi (r_1^2 - r_2^2)$.

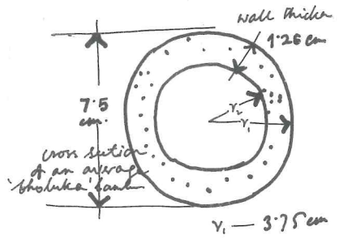
$= 3.1416 (3.75^2 - 2.25^2)$

$= 3.1416 (14.0625 - 5.0825)$

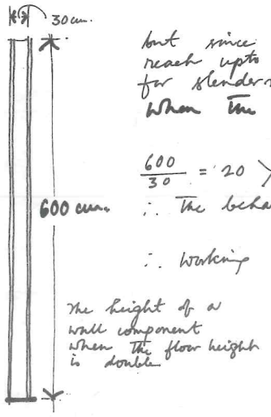
$= 3.1416 \times 9$

$= 28.2744$.

Ans for safety $\rightarrow$ 25 cm².



Safe allowable compressive stress for bamboo $\rightarrow$ 105.5 Kg/cm². (1500 p.s.i).



but since the height of the component may reach upto 6 M. the same should be checked for slenderness ratio. (in case of mazaanin when the floor height may be double).

$\frac{600}{30} = 20 > 15$

$\therefore$ The behaviour will be like a long column.

$\therefore$ Working stress $\rightarrow$ permissible stress $\times$ reduction factor.

The height of a wall component when the floor height is double

$= 105.5 \times \left(1.5 - \frac{600}{30 \times 30}\right)$.

$= 105.5 \times (1.5 - .67)$.

$= 105.5 \times .83$.

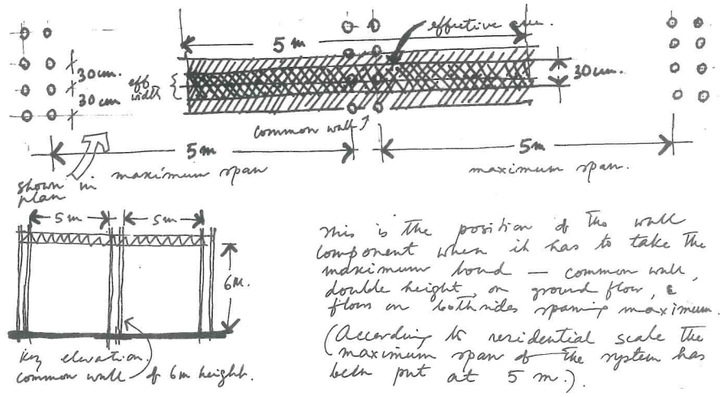
$= 87$ Kg/cm².

$\therefore$ Axial load taken by one bamboo of average diameter of 7.5 cm $\Rightarrow$ 87×25

$= 2175$ Kg.

Load bearing capacity of the wall component.

Since a pair of whole bamboos or four half bamboos (see detail) come at every 30 cm the effective area for loading on these two whole bamboos will be equal to 30 cm x span.



This is the position of the wall component when it has to take the maximum load — common wall, double height, on ground floor, & floors on both sides spaning maximum. (According to residential scale the maximum span of the system has been put at 5 m.).

Effective area for two whole bamboos or four half bamboos $\Rightarrow$ $30 \times 250 \times 2$

$= .75 \times 2$

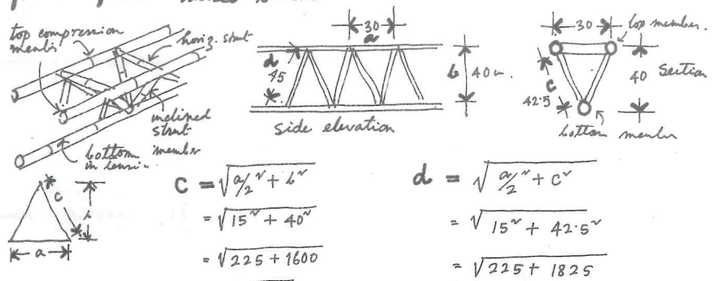
$= 1.5$ m².

Total load coming on two whole bamboos $\Rightarrow$ Live load + dead load.

$= 150 \times 1.5$ + dead load.

$= 225$ + dead load.

Dead loads $\Rightarrow$ from floor framed beam



$C = \sqrt{\frac{a}{2}^2 + b^2}$

$= \sqrt{15^2 + 40^2}$

$= \sqrt{225 + 1600}$

$= \sqrt{1825}$

$= 42.5$ cm.

$d = \sqrt{\frac{a}{2}^2 + C^2}$

$= \sqrt{15^2 + 42.5^2}$

$= \sqrt{225 + 1825}$

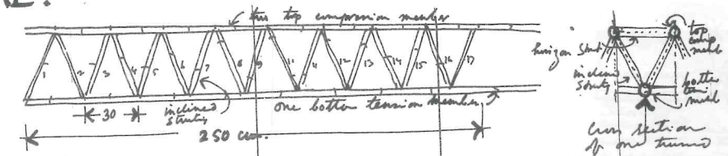
$= \sqrt{2050}$

$= 45$ cm.

length of horizontal struts $\rightarrow$ 30 cm.
length of inclined strut $\rightarrow$ 45 cm.

DERIVATION OF THE SYSTEM.
BASIC STRUCTURE.

LOAD BEARING CAPACITY OF THE MAIN STRUCTURAL WALL COMPONENT.



length of strut → 34 X d = 34 X ·45 → 15·30 M.
horizontal 34 X a = 34 X ·3 → 10·20 M.

length of top & bottom members of the beam → 2 X 2·5 = 5 M → 5·00 M.

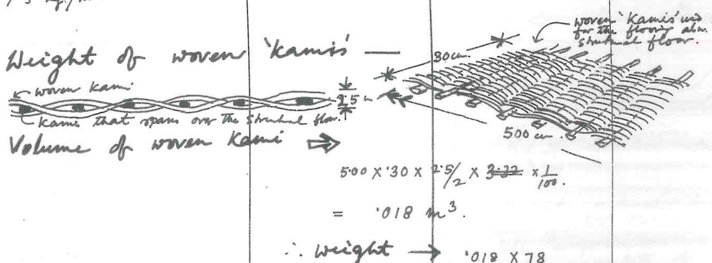
∴ total length → 30·50 m.

∴ for 500 cm length of beam ⇒ 30·50 X 2
= 71 m.

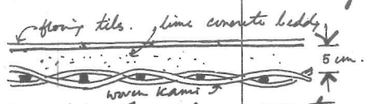
Therefore weight of jati variety of bamboo = 30·50 X 7·3 X 2
= 222·65 X 2
= 445·30 Kg.

Weight of jati variety of bamboo is 7·3 Kg/m.
bamboo used for inclined struts is sal variety and this variety of bamboo of 5 cm diameter is almost equal to 7·5 Kg/m.

Weight of woven 'kamis' —



Volume of woven kami ⇒
5·00 X ·30 X 2·5/2 X 3·32 X 1/100.
= ·018 m³.
∴ weight → ·018 X 78
= 1·56 Kg.



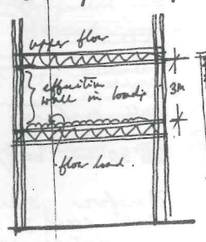
Weight of lime concrete ⇒ ·15 X 5 X ·3 X 2400.
= 180 Kg.
2400 will include the weight of voids and iron strip used in the triangular trussed beam.

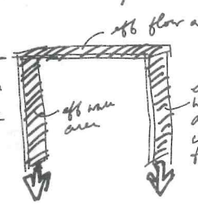
weight of tiles etc ⇒ ·3 X 5 X 90 = 135 Kg.

∴ total dead load ⇒ 446 + 1·6 + 180 + 135 = 767 Kg.

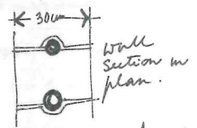
∴ total load from first floor ⇒ 767 + 225 = 992 Kg.

load from upper storey —

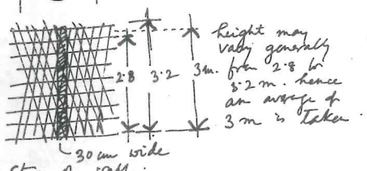


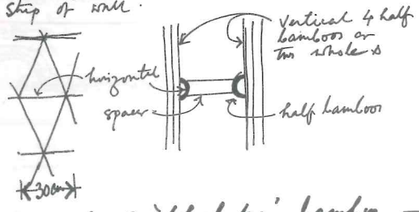


Now the load from upper storey will include the weight of the wall also in addition to the floor weight.



length of two whole bamboos 3 X 2 ⇒ 6 m.
length of horizontal bamboos (16 half bamboos) 8 X ·3 ⇒ 2·4 m
length of spacer 8 X ·1 ⇒ ·8 m.
∴ total length → 9·2 m

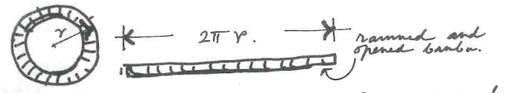




weight of 'bhaluka' bamboo per metre is 14·6 kg. Since the spacer 'sal' variety is taken as 'bhaluka' this will include the weight of bolt also.

weight of 'bhaluka' bamboo ⇒ 9·2 X 14·6
= 134·32 Kg.

Weight of rammed bamboo used as lath for plastering ⇒

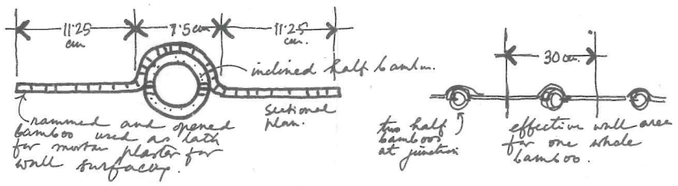


One bamboo of 'r' radius when rammed and opened will cover a width equal to 2πr and length according to its length
radius of average bamboo is 3·75 cm.
therefore width of one rammed and opened bamboo ⇒ 2 X 3·1416 X 3·75 = 23·5 cm.

DERIVATION OF THE SYSTEM.
BASIC STRUCTURE.

LOAD BEARING CAPACITY OF THE MAIN STRUCTURAL WALL COMPONENT.

IT HAS BEEN FOUND THAT WITH THIS FIXED SPACING AND INCLINATION OF THE HALF BAMBOOS THE BEARING CAPACITY CAN MEET WITH MORE THAN A GROUND FLOOR STRUCTURE. THE BEARING CAPACITY CONFIRMS TO BEAR THE LOAD OF **GROUND AND TWO** (THE ACTUAL BEING 2·4) **UPPER FLOORS OF NORMAL HEIGHT** (UPTO 3·2 M) IN THIS SYSTEM.



23·50 cm ⇒ 11·25 × 2.

Therefore one and a half rammed and opened bamboo shall cover 30 cm width of the wall which is equal to the effective wall width for one whole bamboo in bearing.

Hence bamboo required for both surfaces of the wall

⇒ 3 × 1·5 × 2

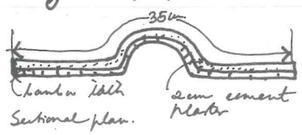
= 9 m length.

'Jati' variety is preferable for this lathing

(weight of 'jati' bamboo is 7·3 kg/m.) hence weight = 9 × 7·3

= 65·7 kg.

Weight of plaster ⇒



width of plaster ⇒ 11·25 × 3 = 33·75 cm.

say ⇒ 35 cm

length ⇒ 3 m.

thickness ⇒ 2 cm

Therefore weight ⇒ ·02 × ·35 × 3 × 2 × 2400. = 100 kg.

Therefore total wall load on two whole bamboos or four half bamboos of the load bearing component ⇒ 134·32 + 65·7 + 100

300·02 kg.

Now total load from upper floor on two whole bamboos will be ⇒ floor wt + wall wt.

992 + 300.

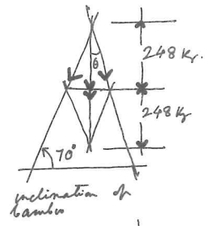
⇒ 1292 kg.

Since load from upper floor and first floor weight is known, also the capacity of two whole bamboos — the no of storey or floors may be found by proportioning the same.

Weight on one half bamboo from the first floor only ⇒ 992/4 = 248 kg.

Weight on one half bamboo from upper storey (floor & wall) ⇒ 1292/4 = 323 kg.

Actually the bamboos subjected to loading are at an inclination of 70° to the horizontal so hence the actual load acting on the bamboo will be different than when it is vertical.



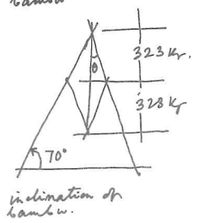
θ ⇒ [180° − (70° + 70°)] × ½ ⇒ 20°.

Therefore actual axial load on one inclined bamboo from first floor only will be —

248 / cos 20°

= 248 / ·939.

= 264 kg.



And actual axial load on one inclined bamboo from upper storey (floor & wall loads) will be —

323 / cos 20°

= 323 / ·939.

= 344 kg.

Now, axial load bearing capacity of one half bamboo in compression ⇒ 2175/2 = 1087·5 kg.

load from first floor ⇒ 264 kg < 1087·5

Therefore the remaining bearing capacity of bamboo in the system may be proportioned for the upper floors.

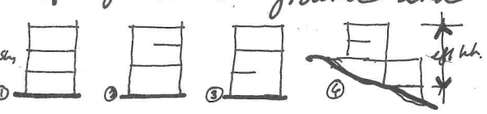
∴ No. of upper floors ⇒ (1087·5 − 264)/344

344 is the loading from upper storey.

= 2·4 floors.

Hence safe no of floors is ground and two uppers.

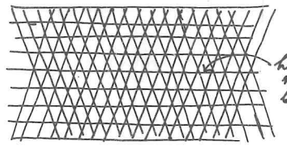
① ground & two upper
② ground & one double wt storey
③
④ diff. height shall be adp. in ground & two upper



DERIVATION OF THE SYSTEM.
BASIC STRUCTURE.

CHECK FOR THE STRESSES DEVELOPED IN THE MAIN STRUCTURAL COMPONENTS (WALL, FLOOR AND ROOF STRUCTURE).

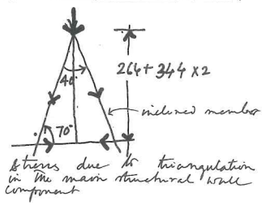
Check for the tensile stress in the horizontal member of the system of the wall.



Since loading on the member will be more & more towards the base and maximum at the lowermost member therefore checking has been done to the same.

344x2 → for two floors.

STRESS IN HORIZONTAL TENSION MEMBER OF WALL COMPONENT.



tension ⇒ $\sin 20° \times (264+344\times2)\times2$

$= \cdot342 \times (264+688)\times2$

$= \cdot342 \times 952 \times 2$

$= \cdot342 \times 1904$

$= 651.168$ Kg.

SAFETY OF THE UNSUPPORTED LENGTH OF THE MAIN STRUCTURAL INCLINED MEMBERS.

Since the tension members are half bamboos tension taken by one half bamboo is considered.

tension taken by one half bamboo

⇒ $25/2 \times 158.19$ (area → $25\,cm^2$, tensile stress 158.19)

$= 1977 > 651.168$ Kg.

∴ Safe.

SAFETY OF SPAN OF FLOOR AND ROOF COMPONENT.

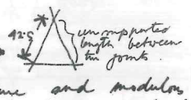
$651\times3 \rightarrow 1953 < 1977$. Therefore notching, holes etc may safely be made upto half the cross sectional area of the bamboo.

STRESSES DEVELOPED IN THE UPPER AND LOWER TIERS OF FLOOR AND ROOF COMPONENT.

Safety in compression ⇒ Since the floor height & members of floors etc have been found basing on the permissible compression load or the buckling capacity of the half bamboo therefore it is safe.

SAFETY OF CUTTING GROOVES, NOTCHING, BORING HOLES ETC. IN THE STRUCTURAL MEMBERS.

Check for the unsupported length of the inclined compression member. ⇒



M.R. (P.S.I)	M.E. (P.S.I.)	
13,600	1960	Sal
18,700	2300	
13,600 + 4620	2220 + 340	Bamboo
18,600 + 4800	2560	
11,400	1620	Teak
15,100	1880	

modulus of rupture and modulus of elasticity of bamboo are almost equal to that of 'teak' and 'sal' wood.

therefore length and cross sectional dimension ratio will be almost same.

timber strut — 4"x6" length 12'

i.e. 12.

bamboo $3.75 \times 12 \rightarrow 4500 > 42.5$ cm safe.

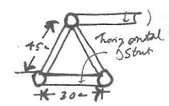
Strut length of the triangular beams —

horizontal → 30 cm.

inclined → 45 cm.

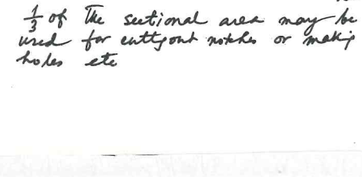
$7.5\times12 \rightarrow 90$ cm > 30 safe.

$5\times12 \rightarrow 60 > 45$ safe.



The roofs of the floor & roof may be considered as a combination of several adjacent triangular beams put together.

Fixing of the span ⇒



This type of trussed beam in timber is safe when the span is 15 times the depth of the beam.

Stress of bending & M.E. of bamboo being very much similar to timber the span has been fixed accordingly & this.

$15\times40 \rightarrow 600$ cm.

taken 500 cm. ∴ safe.

Check for tension & compression members.

load per metre run → $\frac{\text{live load} + \text{dead load}}{5}$

$= \frac{225+767}{5}$

$= \frac{992}{5} = 198.4$ Kg/m.

Bending Moment → $\frac{WL}{8}$

$= \frac{198.4\times5\times5}{8} = 24.8\times25 = 62000$ Kg.cm.

Moment of resistance → $= A_{lt} \times t_t \times d$

A_{lt} → area in tension

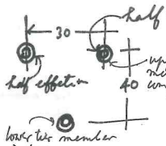
t_t → tensile stress.

d → depth of beam.

∴ actual stress → $t_t = \frac{62000}{28.27\times40}$

$= 56.4 < 158.19$

∴ safe.



∵ this stress is < half the permissible stress cutting & notching etc upto 50% may be allowed.

area reqd for compression ⇒ $A_{lc} = \frac{M.R.}{C_l \times d}$ (C_l → compressive stress. A_{lc} → area in comp.)

$= \frac{62000}{105.5\times40} = 14.7\,cm^2$.

actual area $28.27\,cm^2 > 14.7\,cm^2$

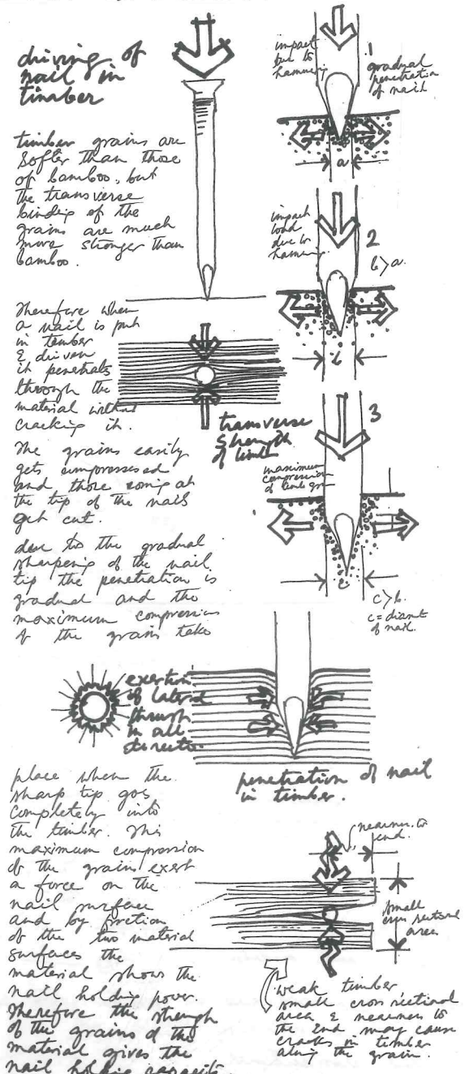
∴ safe.

$\frac{1}{3}$ of the sectional area may be used for cutting out notches or making holes etc

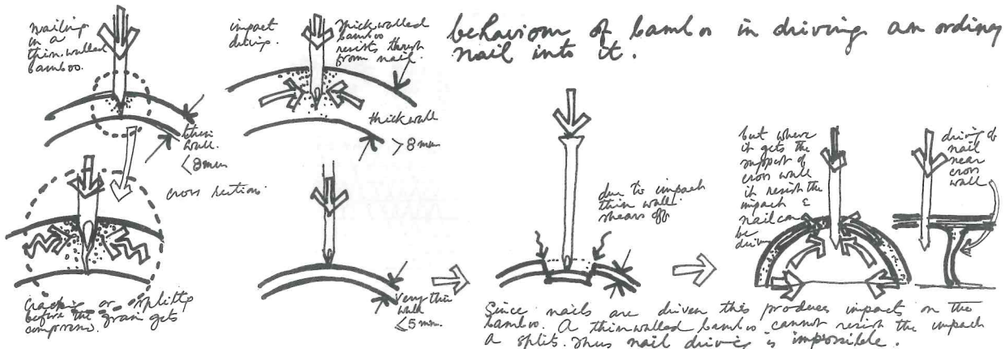
DERIVATION OF THE SYSTEM.

DESIGN OF A NAIL FOR BAMBOO.

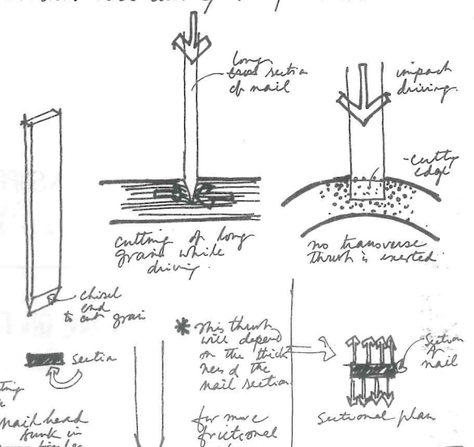
NO NAIL HAS BEEN USED IN BAMBOO CONSTRUCTION THAT IS DESIGNED FOR BAMBOO. ILLUSTRATED IS A STUDY OF THE MATERIAL BEHAVIOUR WHILE DRIVING AN ORDINARY NAIL INTO IT AND A NAIL DESIGN FOR USE IN BAMBOO CONSTRUCTION.

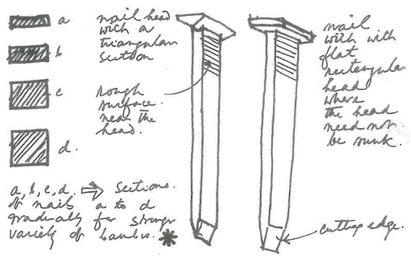


Since the nail used for timber is round it exert force equally in all direction. Strength along the grains are always much more than the transverse. Therefore cracks or splitting never occurs across the length but along it.



Bamboo is weak in transverse strength. This is because of the weak binding substance in the material and lack of cross grains (except in the cross walls). But a round nail designed for timber, exerts force in all direction, and bamboo being weak in transverse strength it cracks or splits along the grain. The transverse strength depends on the wall thickness of bamboo. Hence thick walled bamboo can resist the driving of nails while the thin walled cannot. The bamboo splits before the grain gets compressed.





Therefore a nail may be designed which exert lateral thrust in one direction only ie along the grains. A flat rectangular section with a chisel type tip ie cutting edge will serve the purpose. This will cut across the grains and penetrate without exerting any thrust transverse to the long grains. The head, in the similar way may be a rectangular one with or without a bevelled & underside.

A SYSTEM OF BUILDING CONSTRUCTION WITH BAMBOO AS THE PRINCIPAL MATERIAL.

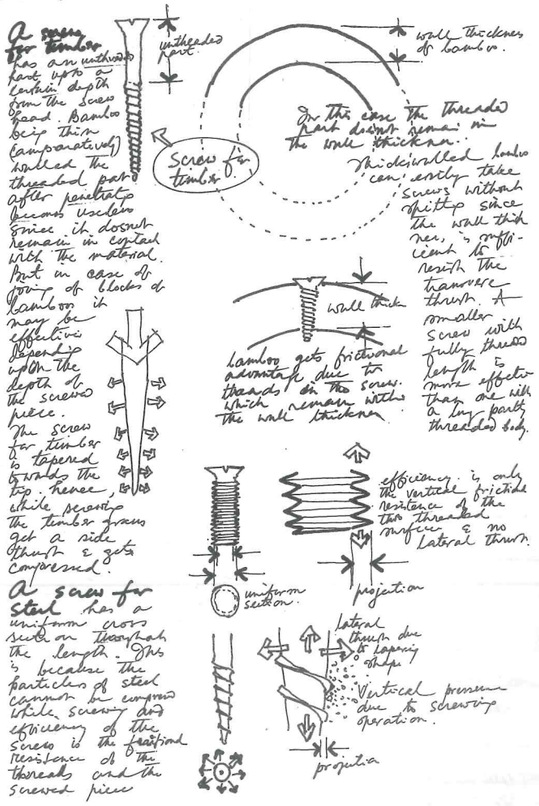
12.

DERIVATION OF THE SYSTEM.
SCREW, BOLT AND TIE GRIP.

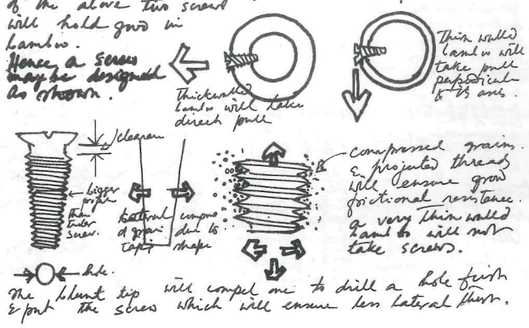
A SCREW FOR TIMBER AND A SCREW FOR STEEL ARE NOT ALIKE SINCE THE DESIGNS ARE FOR TWO DIFFERENT MATERIALS. HENCE FOR BAMBOO, BEING A DIFFERENT MATERIAL, THE SCREW TO BE USED MAY BE DIFFERENT FROM THE FORMER TWO.

IN BAMBOO CONSTRUCTION THE WORKING OF A BOLT REMAINS SAME. BUT THE **SURFACE BEING CURVED** THE TRANSFER OF STRESS FROM THE BOLT TO THE SURFACE WILL CHANGE. BORING A HOLE FOR PUTTING THE BOLT IS IMPORTANT.

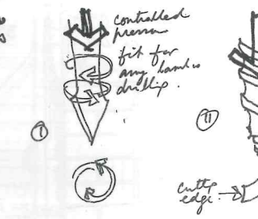
BAMBOO HAS A SMOOTH SURFACE. DUE TO CURVED SURFACE THE PORTION IN CONTACT BETWEEN TWO BAMBOOS IS A MINIMUM. THE STATIC QUALITY OF A KNOT OR TIE IN BAMBOO DEPENDS ON THE FRICTION BETWEEN THE TYING MATERIAL & BAMBOO. HENCE A SURFACE OF GOOD FRICTIONAL RESISTENCE WILL GIVE A PROPER STATIC GRIP.



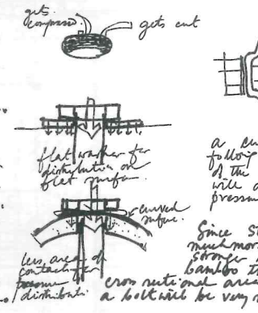
Since bamboo takes less lateral thrust than wood but has stronger long grain a combination of the above two screws will hold good in bamboo.
Hence a screw may be designed as shown.

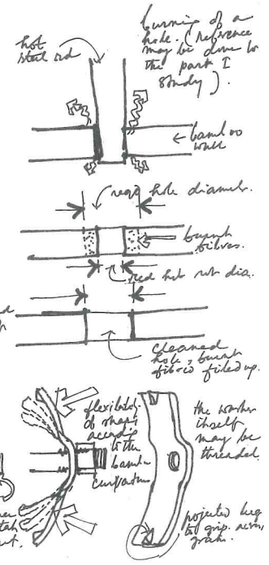


drilling in bamboo is possible provide in doorway extent heavy lateral thrust. The drill shown in (I) is safe since the pressure can be controlled and the hole may be made with less lateral pressure. In the II nd case since the drill penetrates by screw action the lateral thrust cannot be controlled. A burnt hole is very safe a doorway exert any lateral pressure.

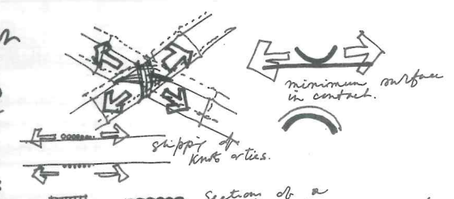


A flat washer under the bolt head will not transfer the pressure over a larger area. A washer which follows the curvature of the surface will distribute the load over a larger area.



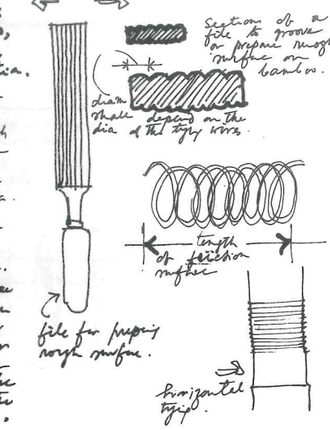


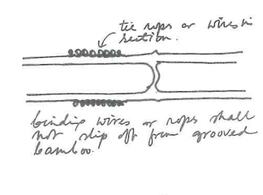
However tight is the tying a knot always slips in bamboo if the bamboos are tied in the natural form since the friction between two smooth & curved surfaces is very very less, it need from the existing construction.

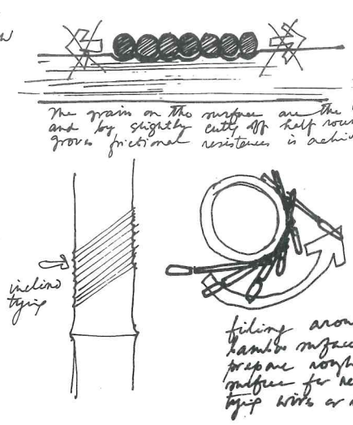


So by giving a roughness to the surfaces in contact the knot may be prevented from slipping off from the original position.

Illustrated is a derived system for the purpose. The bamboo surface is filed to roughen and to recieve the tying rope or wire. Efficiency of the tie shall be proportional to the number of turns.



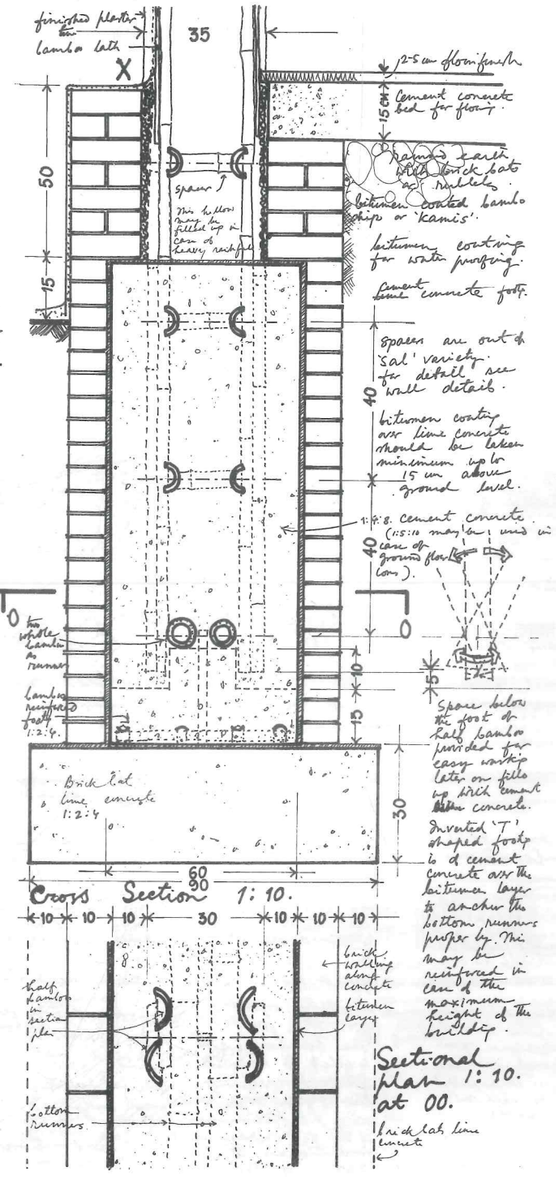


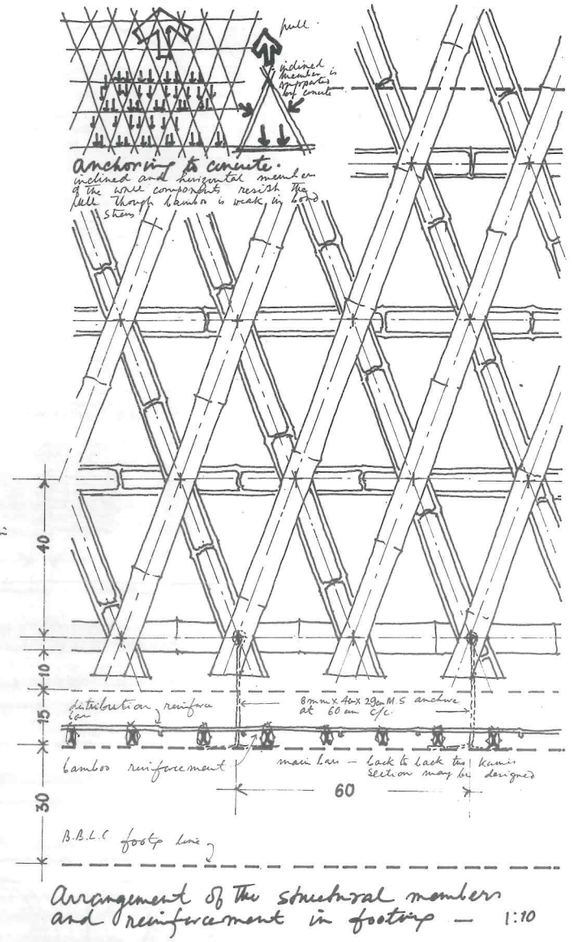


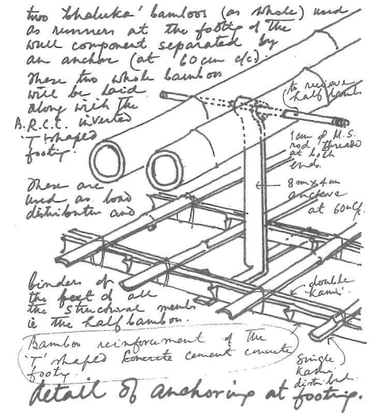
A SYSTEM OF BUILDING CONSTRUCTION WITH BAMBOO AS THE PRINCIPAL MATERIAL.

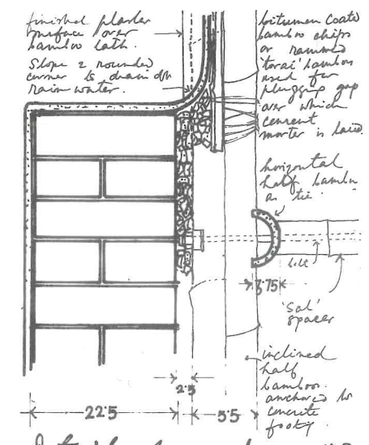
DERIVATION OF THE SYSTEM.
THE FOUNDATION COMPONENT.

THE MAIN LOAD BEARING INCLINED HALF BAMBOOS ARE ANCHORED TO AN EXTRA B.R.C.C. INVERTED 'T' SHAPED FOOTING WITH TWO WHOLE 'BHALUKA' BAMBOOS USED AS BOTTOM RUNNERS FOR DISTRIBUTION OF LOADING. THIS FOOTING SITS ON A B.B.L.C. FOUNDATION BASE. WATER PROOFING IS DONE ACCORDING TO DEGREE OF RAINFALL AND SITE OF CONSTRUCTION. THIS BOTTOM HEAVY CONSTRUCTION WILL GIVE A FIRM BASE TO THE STRUCTURE FOR PROTECTION AGAINST EARTH TREMOR.





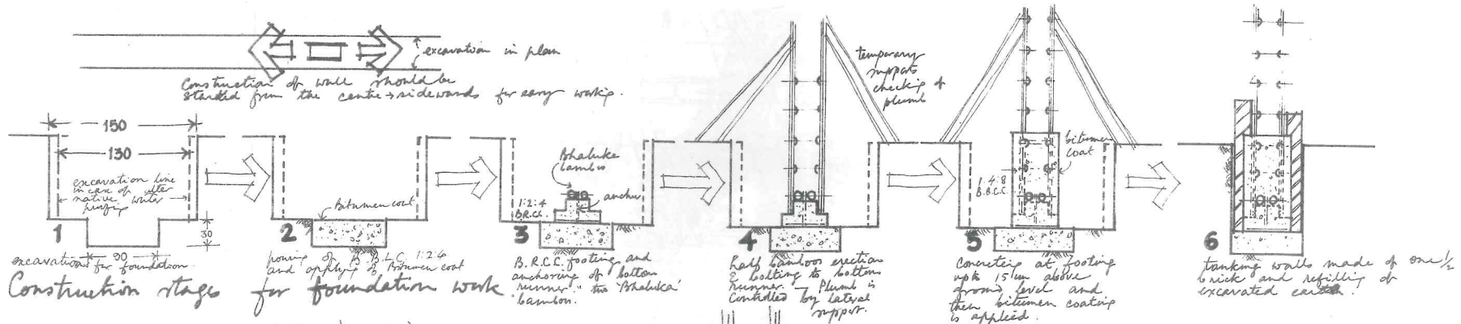


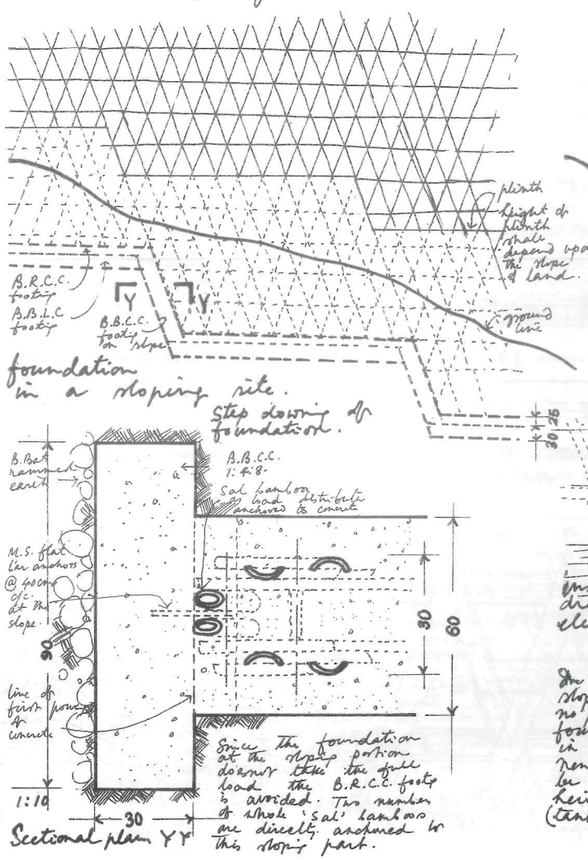


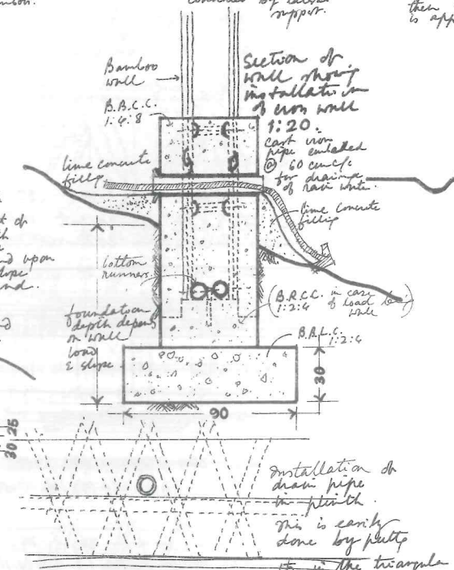
The load bearing wall component is anchored to the concrete foundation as shown the cross section and the load distribution is done by the two whole bamboos of the bhaluka variety which are anchored to the cement concrete footing (B.R.C.C.). Reinforcement to this footing may be avoided in case of ground floor structure and non-load bearing cross walls. Spacing & cross sectional area of the reinforcement bamboo may be worked out in a systematic procedure concerned profiled by the tank-jo method or shown and in case of less raining area and where sub-soil water is no problem only the half lamboo may be impregnated in bituminous before use the cement is poured (detail of which is followed).

DERIVATION OF THE SYSTEM.
FOUNDATION COMPONENT.

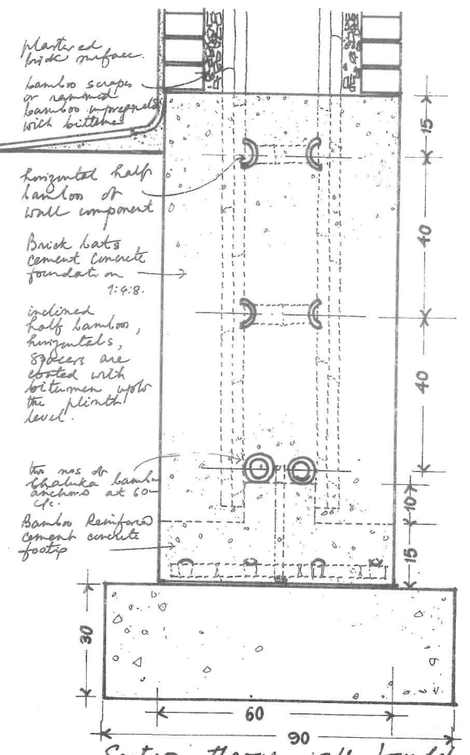
FOUNDATION IN A SLOPING GROUND SHALL FOLLOW THE VERTICAL AND HORIZONTAL MODULE OF THE WALL COMPONENT AND THE SLOPE OF LAND. THIS IS DONE BY PROVIDING STEPS. AN **ALTERNATIVE METHOD OF WATER PROOFING** IS TO IMPREGNAT ALL THE BAMBOO COMPONENTS OF FOUNDATION WITH BITUMEN. **RAIN WATER DRAINAGE** IN CASE OF WALLS ACROSS CONTOUR LINES IS NATURAL BUT IN CASE OF WALL ALONG THE CONTOURS DRAIN PIPES ARE TO BE INSTALLED AT INTERVALS.







In case of less rainy area and sloping land where sub-soil water is no problem bitumen coat to the concrete foundation may be avoided and in such case all the bamboo components inside the foundation should be coated with bitumen upto the height of the plinth. So the (tankip) brick walls are avoided.

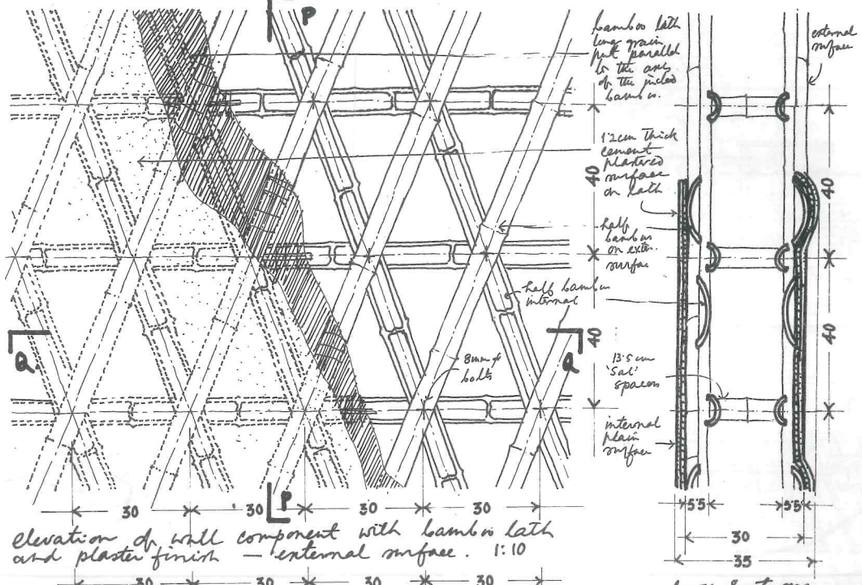


Section through wall foundation for less rainy area and sloping land 1:10.

DERIVATION OF THE SYSTEM.

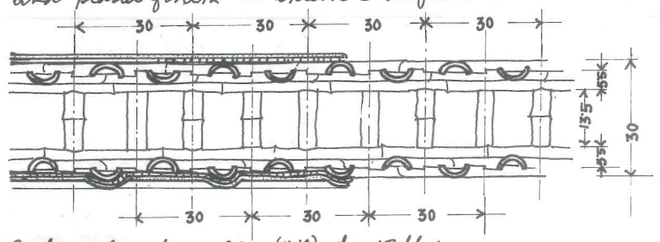
WALL COMPONENT.

THIS LOAD BEARING WALL COMPONENT HAS BEEN DESIGNED TO MEET THE LOAD WHEN A BUILDING REACHES THE MAXIMUM LIMITATIONS OF THIS CONSTRUCTION SYSTEM. THEREFORE WITH THIS FIXED SPACINGS, INCLINATION, SIZES ETC THIS COMPONENT SHALL SAFELY TAKE THE LOAD OF A BUILDING BUILT TO THE FULL LIMITATIONS OF THIS SYSTEM OF CONSTRUCTION.



elevation of wall component with bamboo lath and plaster finish — external surface. 1:10

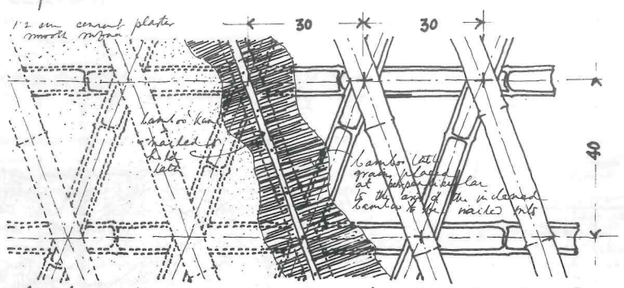
Cross section of wall P-P. 1:10.



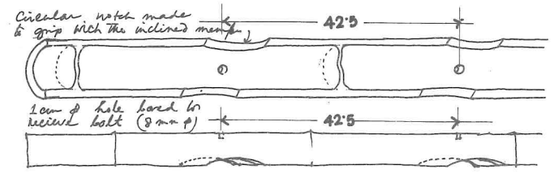
Sectional plan QQ. (1:10) of wall component.

The structure of the wall component is a combination of two wall surfaces separated by spacers at intervals. due to the notching of the half bamboo at junction and triangulation, the whole thing acts as one rigid component for the wall.

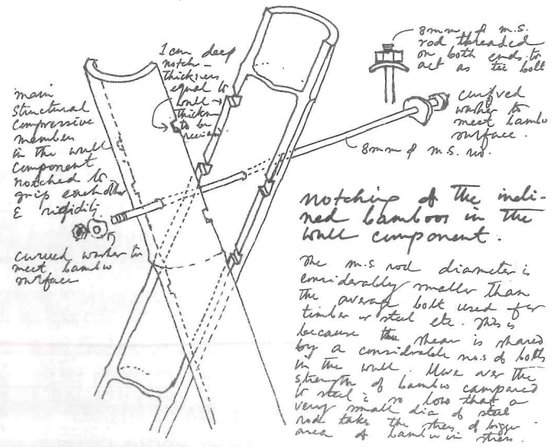
The surface treatment may be done by several ways. The inner surface is kept smooth and the outer wall surface may be so plastered to follow the structural members to enhance the structural beauty & not hide as it were the plan.



elevation of wall component with bamboo lath & plaster finish external surface. 1:10.

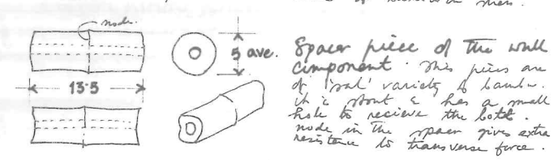


Circular notching of the horizontal ties of the wall component. 1:5.

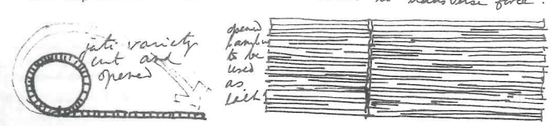


notching of the inclined bamboos in the wall component.

The M.S. rod diameter is considerably smaller than the usual bolt used for timber or steel etc. As because the shear is shared by a considerable no. of bolts in the wall. Also as the strength of bamboo compared to steel is not less than a very small dia of steel rod take the stress of bigger area of bamboo in stead.



Spacer piece of the wall component. This pieces are of 'jati' variety of bamboo. It is about 2 knots or more hole to receive the bolt. node in the spacer gives extra resistance to transverse force.

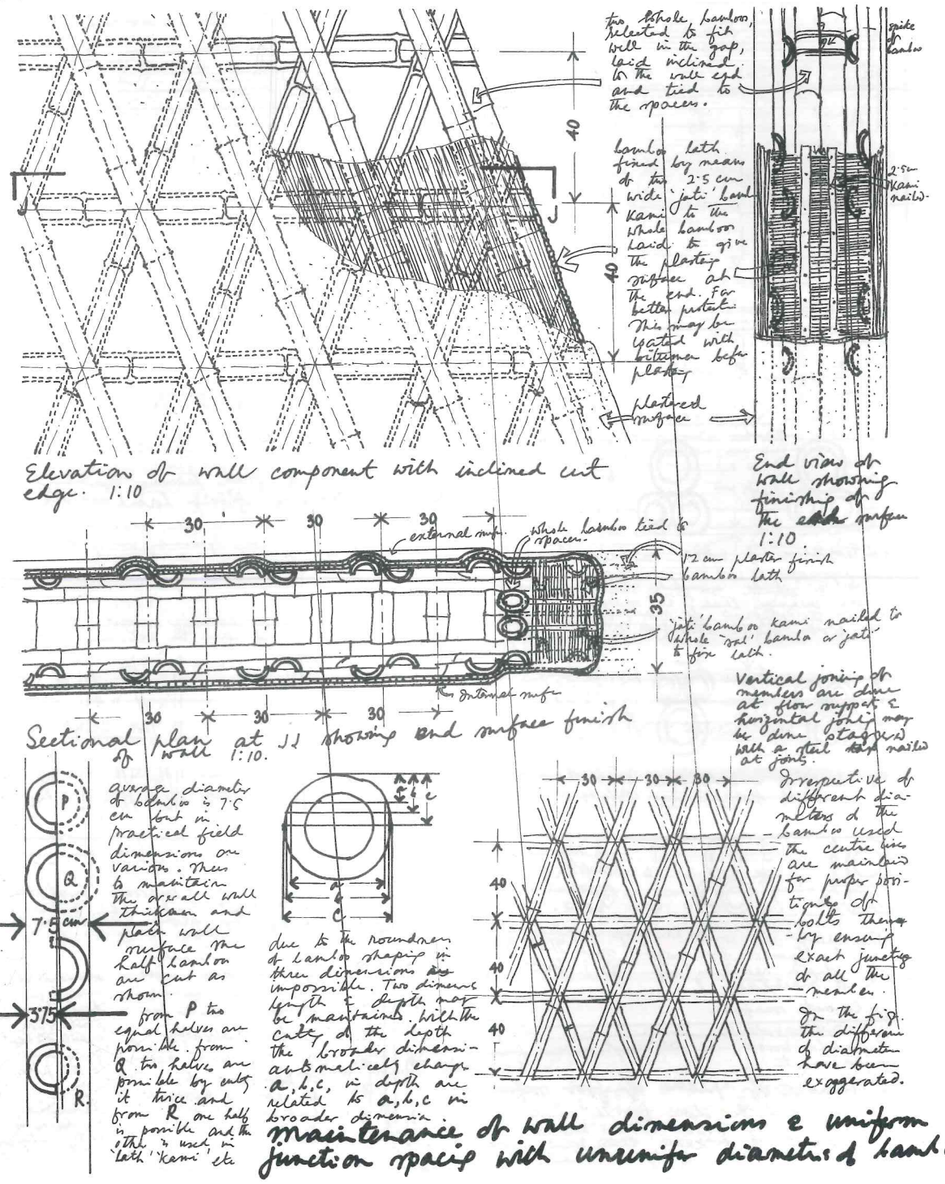


Bamboo lath used for wall surface plastering.

These may be prepared in the conventional way of existing building construction. These are prepared from 'jati' variety of bamboo since the fibres are very short of these bamboos. These are first rammed or cut to break the cylindrical structure and then opened up the loop of nodes are not completely cleared of because it holds the plaster properly. But to remove the cellular part it is advisable to use the external skin of bamboo only.

DERIVATION OF THE SYSTEM.
WALL COMPONENT.

THE FINISHING OF THE SURFACE OF WALL END MAY BE DONE AS SHOWN. IN CASE OF VERTICAL CUT END THE PROCEDURE REMAINS SAME. THE **CROSS WALL JUNCTION** IS IMPORTANT SINCE IT PREVENTS SHAKING OF MAINWALL IN THE DIRECTION PERPENDICULAR TO THE LATER IN CASE OF EARTH TREMOR. THIS MAY BE DONE AS SHOWN. **ADVANTAGES OF USE OF HALF BAMBOOS IN MAINTAINING OF WALL DIMENSIONS AND THE SURFACE PLANES ARE ILLUSTRATED IN THE FIG.**



Elevation of wall component with inclined cut edge. 1:10

End view of wall showing finishing of the earth surface 1:10

Sectional plan at JJ showing end surface finish of wall 1:10.

garage diameter of bamboo is 7·5 cm for in practical field dimensions on various. Mean to maintain the overall wall thickness and plaster wall surface the half bamboo are cut as shown.

from P two equal halves are possible from Q two halves are possible by cutting it twice and from R one half is possible and the other is used in both 'kami' etc.

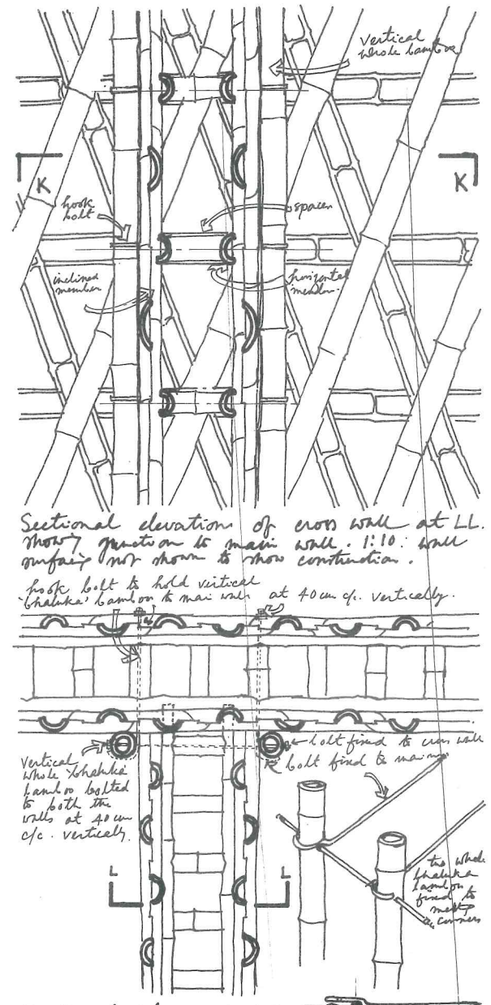
due to the roundness of bamboo shapes in three dimensions it is impossible. Two dimensions length & depth must be maintained. With the change of the depth the broader dimensions automatically change. a,b,c, in depth are related to a,b,c in broader dimension.

Vertical joining of members are done at floor support & horizontal joint may be done staggered with a steel staple nailed at joints.

Irrespective of different diameters of the bamboo used the centre lines are maintained for proper positioning of bolts thereby ensuring exact jointing of all the members.

In the fig. the different of diameter have been exaggerated.

Maintenance of wall dimensions & uniform junction spacing with unevenly diameters of bamboos.



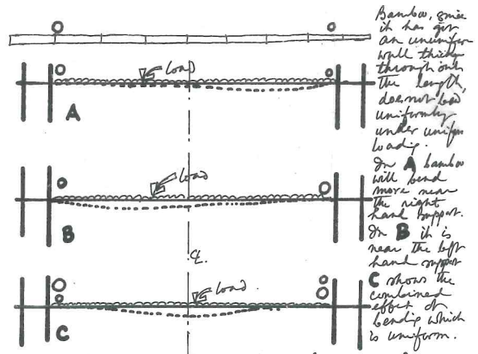
Sectional elevations of cross wall at LL. Mortar junction to main wall. Wall surfaces not shown to show construction.

Sectional plan at K-K showing junction of cross wall & main wall 1:10.

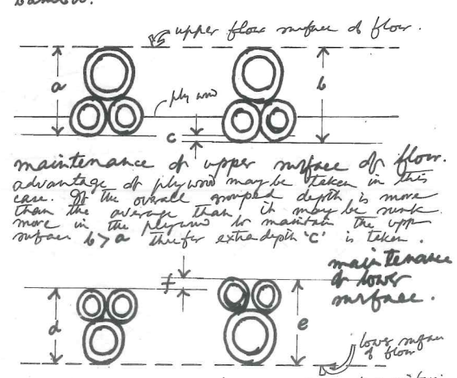
The horizontal members of the cross wall projects into the main wall for proper bonding. Two vertical bamboos are provided at the corners which is fixed to both the walls thereby ensuring fixity of the two walls. The bolt is kept to maintain centre line of the spacer of the main wall.

DERIVATION OF THE SYSTEM.
FLOOR COMPONENT.

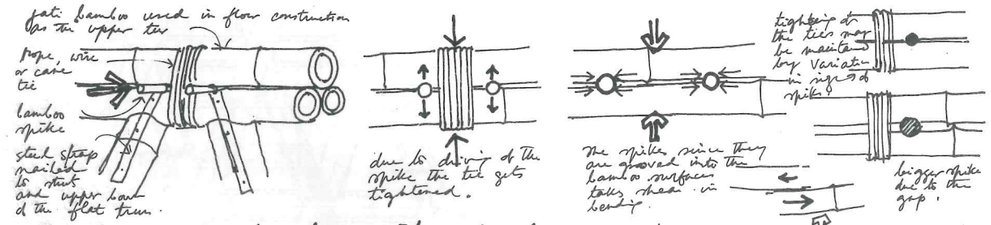
BAMBOO DOESNOT BEND UNIFORMLY DUE TO THE VARIATION IN SECTIONAL AREA ALONG THE LENGTH. UNIFORM BENDING MAY BE ACHIEVED BY GROUPING OF BAMBOOS. PLANES OF FLOORING SURFACE AND BOTTOM CEILING SURFACE MAY BE MAINTAINED AS SHOWN. ADVANTAGES OF BAMBOO SPIKES USED ARE MANIFOLD.— TIGHTENS TIES. RESISTS SHEAR AND MAINTAINS DIMENSIONS. FLAT TRUSSES MAY BE INSTALLED EASILY AS SHOWN. ADVANTAGES AND SAFETY OF THE FLOOR SUPPORTING PLYWOOD HAVE BEEN ILLUSTRATED IN THE FIG.



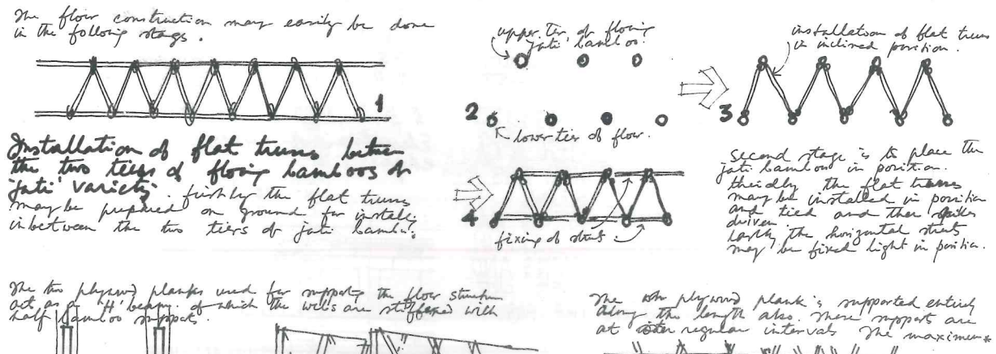
maintenance of uniform bending of bamboo.



Maintenance of plane of floor surface.
This may easily be done by the concrete layer given to the woven bamboo 'kanis'. (due to flexibility of 'kanis' there may become little undulations due to tying or nailing).



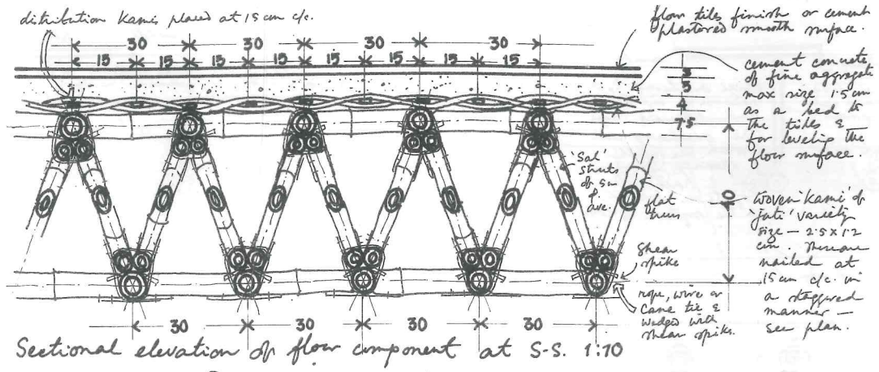
Advantage of spikes driven into gaps of grouped bamboos. It tightens the ties by wedge action and when partially grooved into surfaces of bamboo it takes shear also. (drilling & driving is disadvantageous)



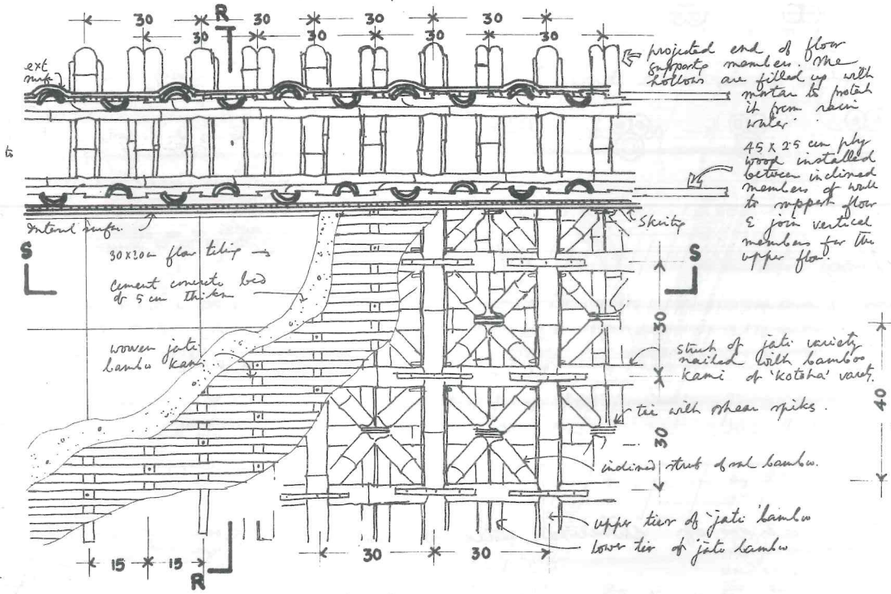
Installation of flat trusses between the two ties of floor bamboos of jati variety.
They may be prepared on ground separately in between the two ties of jati bamboos.

DERIVATION OF THE SYSTEM.
FLOOR COMPONENT.

SINCE BAMBOO IS VERY FLEXIBLE SPANING IS POSSIBLE ONLY BY A TRUSS (WITH ECONOMY) IN THE FLOOR COMPONENT FLAT TRUSSES OF 'SAL' BAMBOO HAVE BEEN INSTALLED BETWEEN TWO TIERS OF 'JATI' BAMBOO BY MEANS OF TIE OF ROPE CANE OR STEEL WIRE AND SHEAR SPIKE WEDGES. DUE INCLINED INSTALLING OF FLAT TRUSSES THE STRUCTURE ACTS AS ONE TOTAL FRAME.

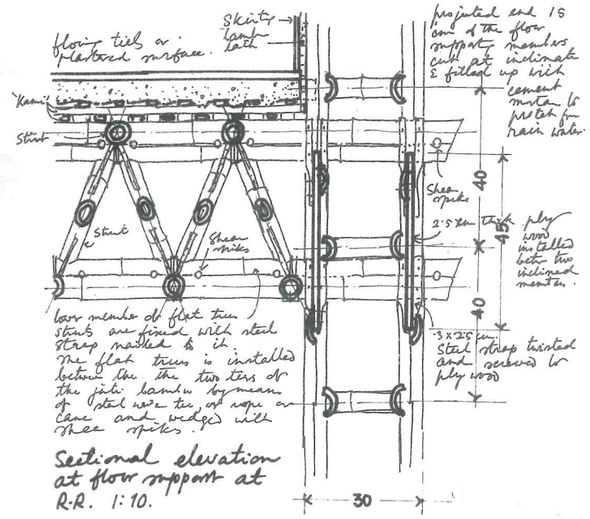


Sectional elevation of floor component at S-S. 1:10

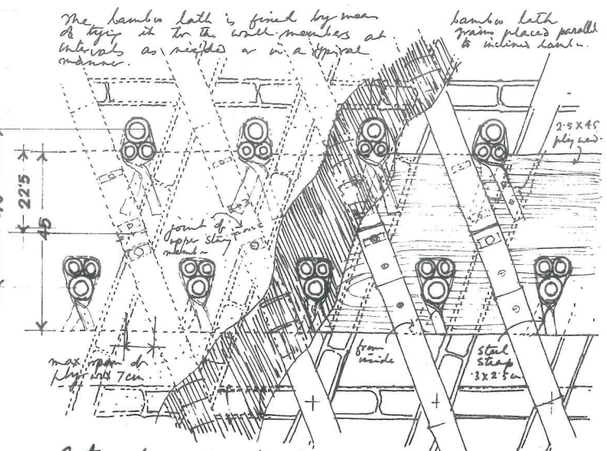


Plan showing floor construction 1:10.

There is a slight variation in the design of the floor support structure. Instead of one 'bhaluka' bamboo in the upper and lower tier of flooring member one jati and two sal bamboos have been provided. This has been done for easy construction and more safety. Justification of safety is that though it increases the dead load of the floor yet it is safe since the actual bearing capacity of the walls comprised is 3·5 floors which is taken as 3 floors. Hence over the increased cross sectional area gives more resistance to the stress involved. Lastly this construction makes the floor a easy construction.



Sectional elevation at floor support at R-R. 1:10.

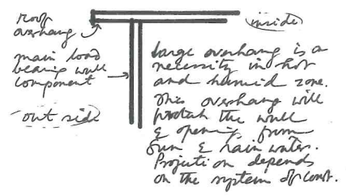


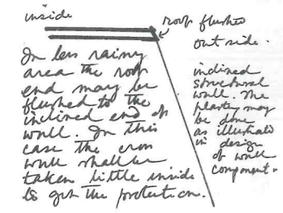
External wall elevation at floor support. 1:10.

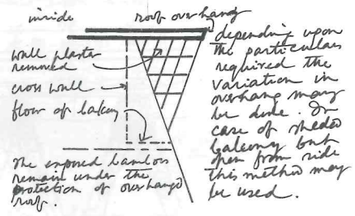
The level of the floor is maintained by adjusting the depth of notch in the plywood this is done because diameter of all the bamboo are not same however the variation is very little. The floor supporting strap are screwed to the plywood by means of steel from both sides. The plywood is secured due to the continuous lateral support of the inclined members.

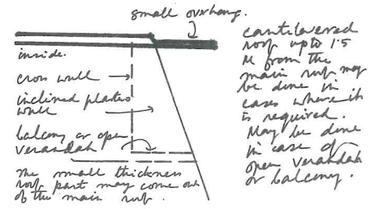
DERIVATION OF THE SYSTEM.
ROOF COMPONENT.

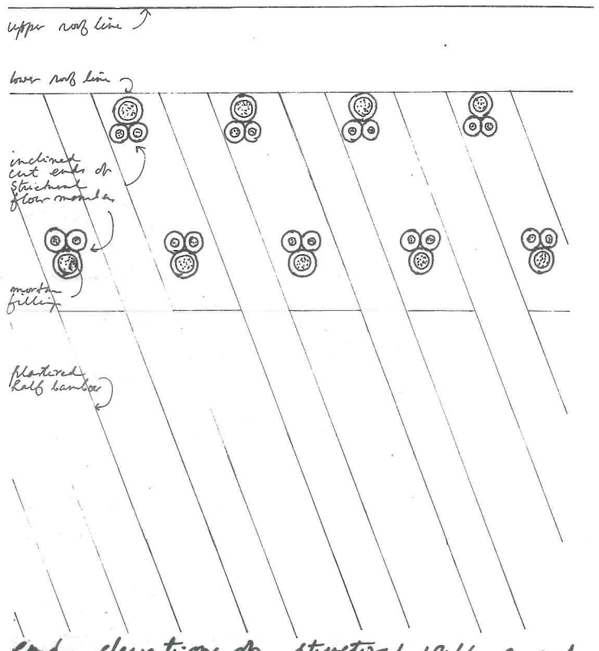
MAIN CONSTRUCTIONS OF ROOF AND FLOOR ARE SAME. THE DIFFERENCE LIES IN THE SURFACING MATERIAL AND OVERHANG. VARIATIONS IN DESIGNING ROOF END DEPEND UPON PARTICULAR CASES. WATER PROOFING AND HEAT INSULATION IS IMPORTANT FOR HOT AND HUMID CLIMATE.





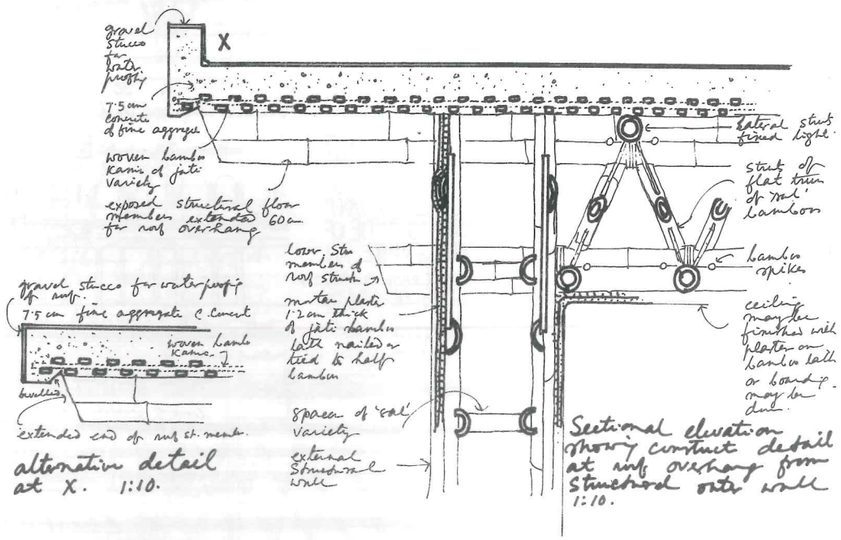






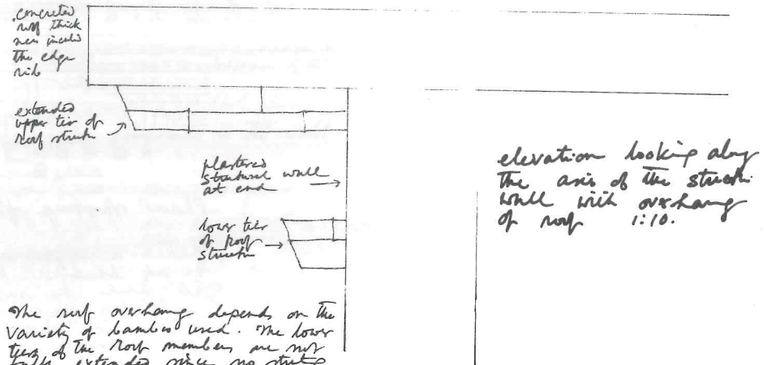
end elevation of structural wall & roof overhang. 1:10

The main structure of the roof is similar to that of floor. The surface concrete is increased in thickness to 7·5 cm for water proofing and heat resistance. The finish surface material is gravel sheets for water proofing — in hot & humid zone the terrace is not often used. In case of use of terrace floor the surface may be done with tiles or tar felt which is laid on the fine aggregate cement concrete. The woven 'kamis' are not reinforcement to concrete but a rough background.



alternative detail at X. 1:10.

Sectional elevation showing construction detail at roof overhang from structural outer wall 1:10.

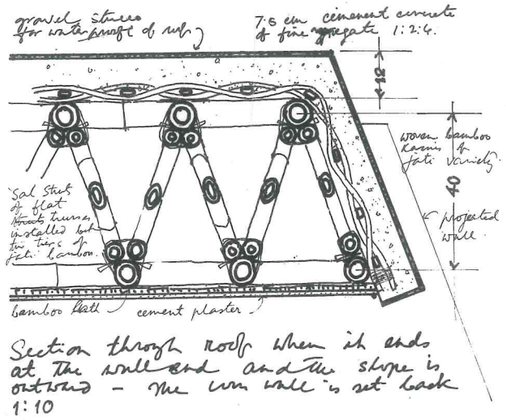


The roof overhang depends on the variety of bamboo used. The lower tiers of the roof members are not fully extended since no strut is required in this part of roof.

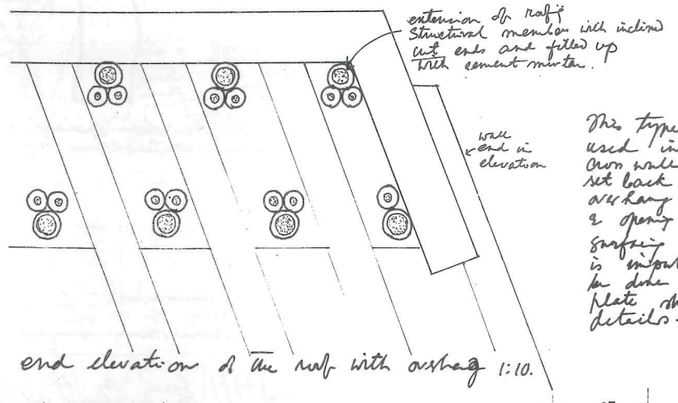
elevation looking along the axis of the structural wall with overhang of roof 1:10.

DERIVATION OF THE SYSTEM.
ROOF COMPONENT.

ROOF DESIGN IS FLEXIBLE. IT MAYBE DESIGNED ACCORDINGLY TO THE PARTICULAR REQUIREMENTS OF A BUILDING TO BE DESIGNED. THE FORM AND APPEARANCE WILL VARY ACCORDINGLY (THE MAIN STRUCTURE REMAINING SAME). GIVEN ARE THE DETAILS OF TWO TYPES OF END TREATMENTS OF ROOF.

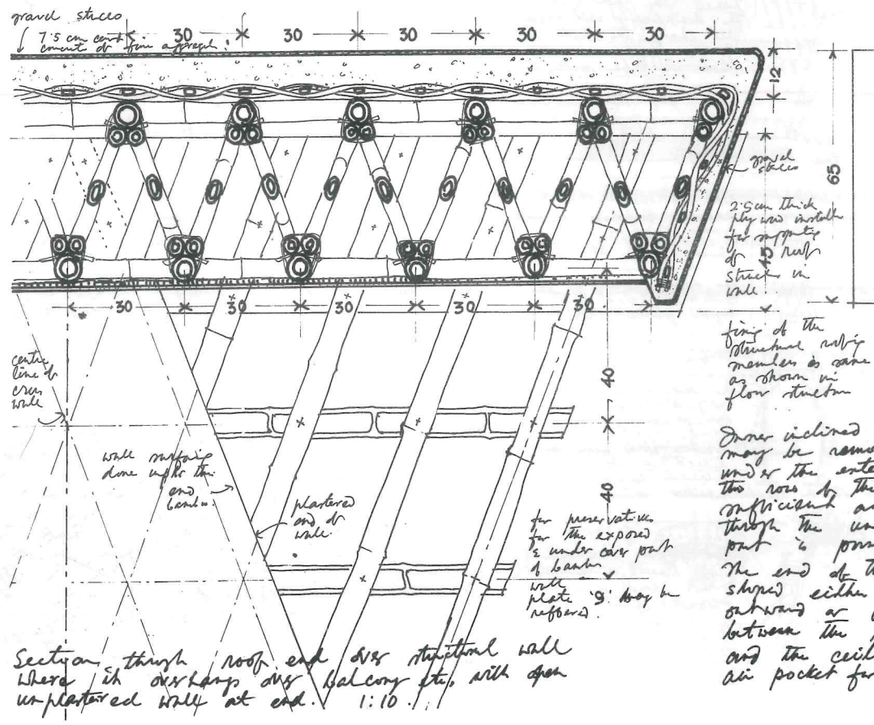


Section through roof when it ends at the wall end and the slope is outward - the cross wall is set back 1:10

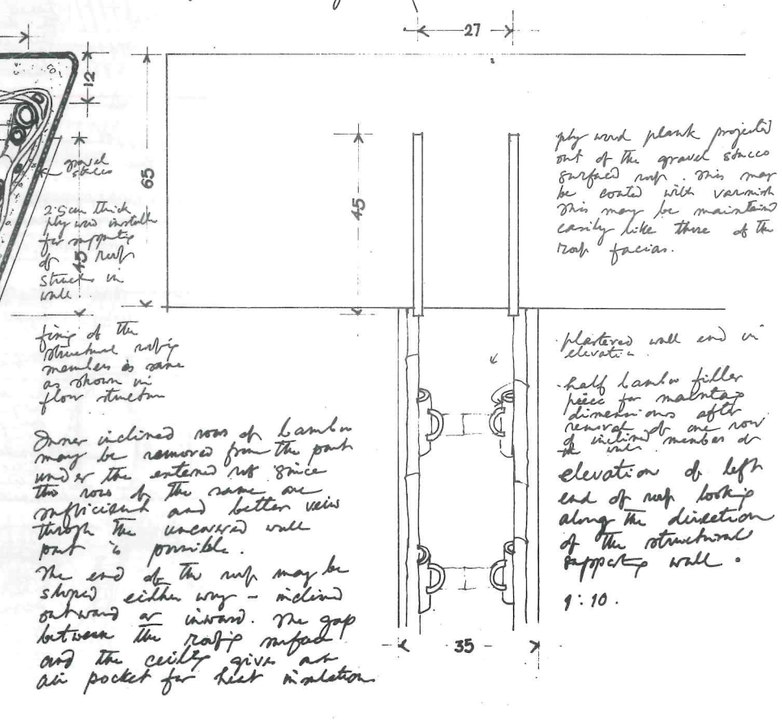


end elevation of the roof with overhang 1:10.

This type of roof may be used in low raining areas, the cross wall shall have a set back so that the roof overhang protects the wall & opening from sun & rain. The surface of the sloppy wall end is unplastered, and this may be done as described in the plate showing wall component details.



Section through roof end over structural wall where it overhangs over balcony etc. with open unplastered wall at end. 1:10



first of the structural roofing members as seen as shown in floor structure

Inner inclined rows of bamboo may be removed from the roof end or the external row since the rows by the eaves are sufficient and better view through the uncovered wall part is possible.

The end of the roof may be shaped either way - inclined outward or inward. The gap between the roofing surface and the ceiling gives an air pocket for heat insulation

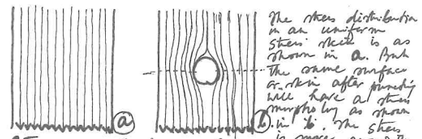
elevation of left end of roof looking along the direction of the structural supporting wall.

1:10.

DERIVATION OF THE SYSTEM.
DOOR COMPONENT.

The form of the door opening is related to the form of human figure and the structure of the house or shelter which is in turn related to the construction system.

SINCE THE WALL COMPONENT IS A STRESSED SKIN PUNCTURING OF IT IS IMPORTANT IN OPENING OUT FOR DOORS. THE DOOR OPENING MAY BE FRAMED WITH A CLOSE RIGID TIMBER FRAME. THE FORM OF THE OPENING FOLLOWS THE FORM OF HUMAN FIGURE AND THE STRUCTURE OF THE WALL.

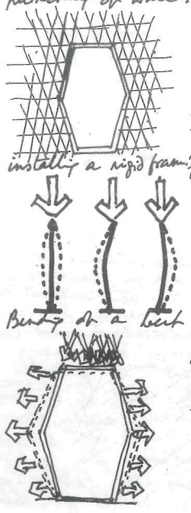


Stress morphology of a punctured stressed skin.

The stress distribution in an uniform stress skin is as shown in a. But the same surface or skin after punching will have a stress morphology as shown in b. The stress is more around the circumference of the puncture.

Stress due to puncturing of wall.

Hence the door opening in the load bearing wall component will change the stress morphology of the wall and the stress will be more around the opening for the door. This stress gradually becomes uniform at a certain distance from the opening.



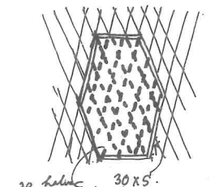
Now to resist this stress around the hole a rigid frame may be installed which will take these increased stress around the door opening. The sectional area of the rigid frame should be sufficient enough to resist the stress which it has to bear.

install a rigid frame

Bent up at best

A vertical member may bent in any direction due to loading. But a bent member after bending will bend in the direction in which it is already bent.

Therefore the rigid door frame thus installed will have a outward thrust and never an inward thrust. But if the lateral opposite thrust is much more than the net result will be an inward thrust which in this case will not happen.

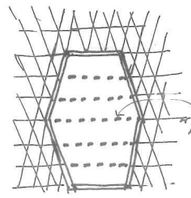


20 halves or 10 whole bamboo

30 x 5

Area of ten half bamboo removed = 28 x 10 = 280 cm²
Area of door frame installed = 150 x 2 = 300 sq.
∴ safe.

teak wood and bamboo is equally strong in thrust axial compression. Now the teak wood door frames have the same dimensions of the members removed shall have to satisfy the cross sectional area.



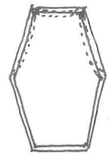
10 halves = 20 whole bamboo.

Area of thrust member removed = 10 x 28/2 = 140 cm²

Area provided in timber frame = 150 x 2 = 300
∴ safe.

Now the safety of bending may be justified like this — The teak wood door frame is much more stronger in bending than that of bamboo which is much more flexible. Now the door frame may be said to be a propped member of bamboo cross sectional area of which is much more than the required. More over 1/3rd of the cross sectional area of the individual trapezoid members are safe to take the load (refer to mathematical derivation of the system) therefore actual area of bamboo reqd is

1/3 x 140 → = 95 cm². But area of teak wood 300 cm². ∴ safe.
5 x 15 → 75 cm.
3 x 30 → 90 cm.
since 300 > 95 cm² safe.



Now the safety of bending may be justified like this — The teak wood door frame is much more stronger in bending than that of bamboo which is much more flexible. Now the door frame may be said to be a propped member of bamboo cross sectional area of which is much more than the required. More over 1/3rd of the cross sectional area of the individual trapezoid members are safe to take the load (refer to mathematical derivation of the system) therefore actual area of bamboo reqd is

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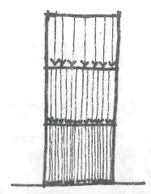
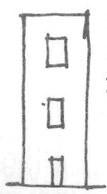


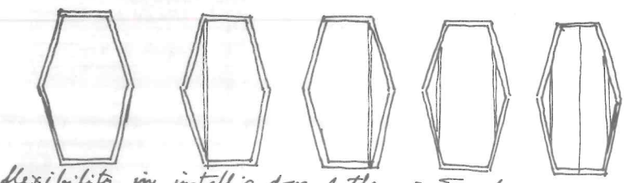
Decrease of load towards the upper floors.



as we go up as many in a tall building the stress on the load bearing component goes on decreasing since the no. of floors above goes on decreasing.

Similar in the wall component with the fixed opening & dimension the opening area may be increased through the 3rd floor (max limit).

This glass pharaoh is clearly seen in the victory tower of chitorgad



flexibility in installing door shutters in the frame.

Now the door frame may be fitted with single shutter or double shutters. These may be vertical hinged or pivotal. These shutters may be any of the conventional type panelled shutter or flush door shutters. Bamboo panelled shutters may be easily be installed.

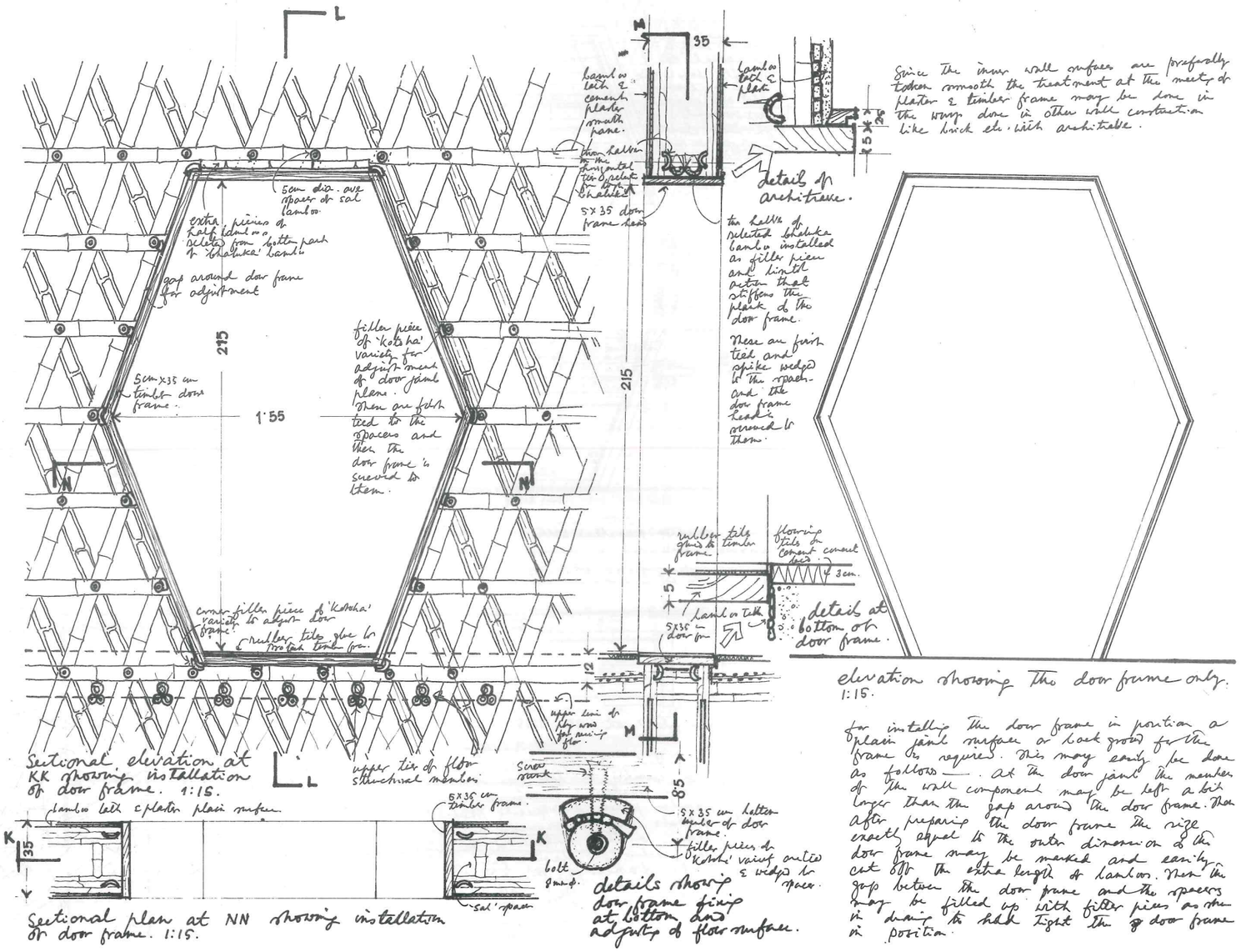
Shutters may be fixed to vertical stud fixed to the main frame.

Bamboo cellular core door shutters may be prepared in small scale industry.

For making door frame sections industrialised method like ply bamboo, glass compressed bamboo mats etc like in the advanced country may be prepared. But as this being an industrially underdeveloped country simple mechanical method of preparing door shutters etc are possible. Therefore, without giving much stress to the industrial preparation of door shutters which at this stage is not very feasible, in following door component mechanically prepared door frame & shutter have been shown.

DERIVATION OF THE SYSTEM.
DOOR COMPONENT.

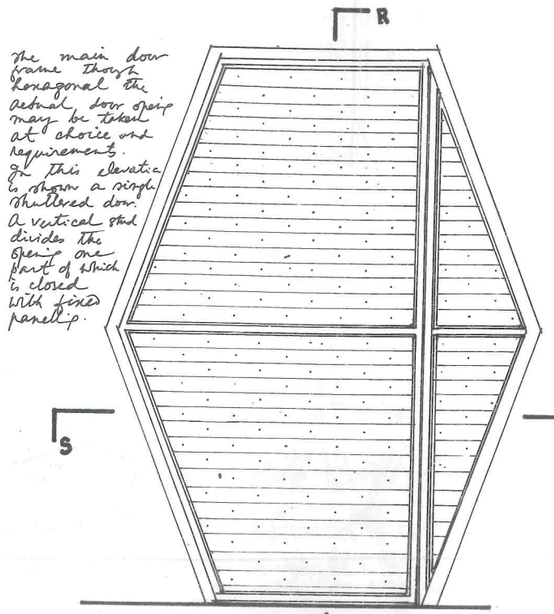
INSTALLATION OF DOOR FRAME MAY EASILY BE DONE AS SHOWN AND INSTRUCTED. PREPARATION OF A PROPER PLANE AT DOOR JAMB AND HEAD IS IMPORTANT. FLUSHIN BOTTOM MEMBER OF DOOR FRAME MAY BE DONE IN THE WAY SHOWN. EXTRA SELECTED HALVES OF 'BHALUKA' VARIETY IS TAKEN FOR THE HORIZONTAL MEMBERS AT LINTOL LEVEL AND DOOR HEAD FILLER PIECES FOR EXTRA SECURITY OF DOOR HEAD.



for installing the door frame in position a plain jamb surface or background for the frame is required. This may easily be done as follows — At the door jamb the member of the wall component may be left a bit longer than the gap around the door frame. Now after preparing the door frame the size exactly equal to the outer dimension of the door frame may be marked and easily cut off the extra length of bamboo. Now the gap between the door frame and the spacers may be filled up with filler pieces as shown in drawing to hold tight the door frame in position.

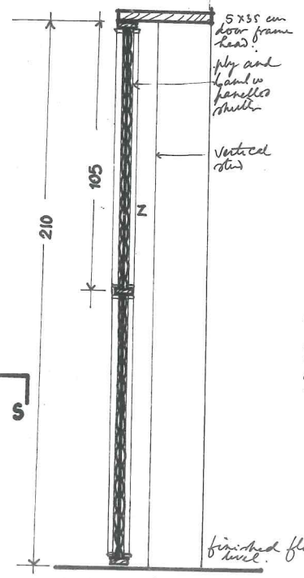
DERIVATION OF THE SYSTEM.
DOOR COMPONENT.

AFTER INSTALLING THE DOOR FRAME THE SHUTTER MAY BE SELECTED FROM ANY SUITABLE MATERIAL WHICH IS UNLIMITED. A SINGLE SHUTTERED BAMBOO PANELLED DOOR IS SHOWN IN THE DRAWINGS.



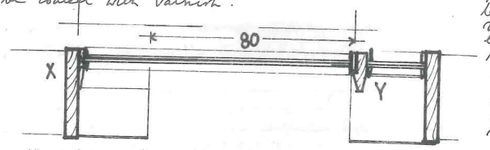
The main door frame though hexagonal the actual door opening may be taken at choice and requirement. In this elevation is shown a single shuttered door. A vertical stud divides the opening one part of which is closed with fixed panelling.

elevation of door with single shutter panelled with bamboo. 1:15



Section at RR 1:15

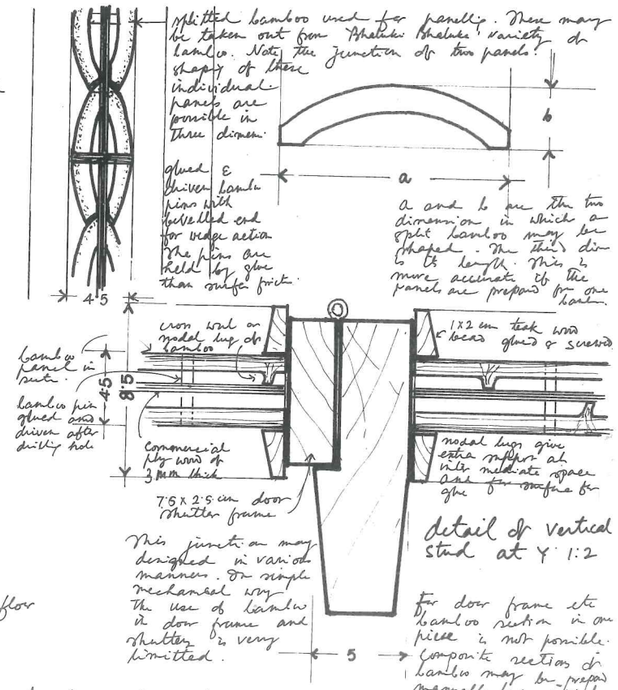
The bamboos used for panelling are preservative treated (the note 9 may be referred) and may be coated with varnish.

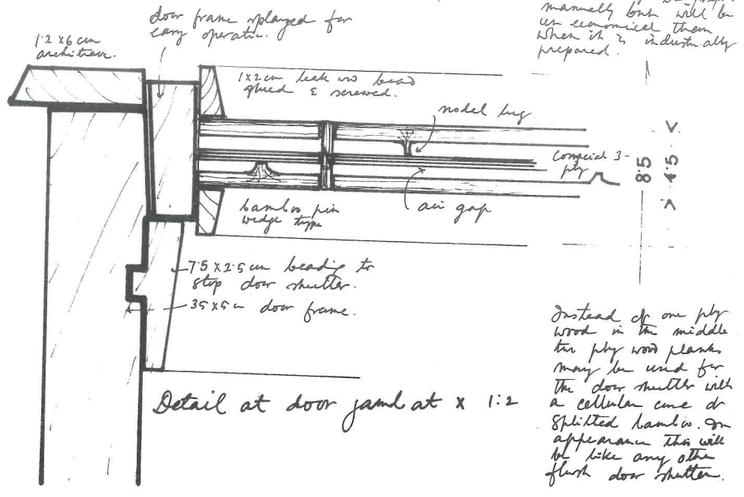


This type of bamboo panelled shutter will be economical and lighter than wooden panelled door. One whole bamboo will cover up the surface for one shutter easily.

Sectional plan at SS. 1:15.

Bamboo panelled shutter may be prepared as follows utilising of bamboo in this type of door is only in the shutter. This shutter is made of 3-ply commercial plank and bamboo panels of 'Bhalki Bhalki' variety. The bamboo panels may be prepared as shown & then glued and pinned on the surface of the plywood from both side. The holes for bamboo pins will be drilled almost equal to the diameter of the pin so that no thread is inserted. The sliding of it will be in glue. This joins and bamboo panels will stiffen the plywood and as a whole stiff panel. Due to the curvature of the panel the whole board get the stiffness.

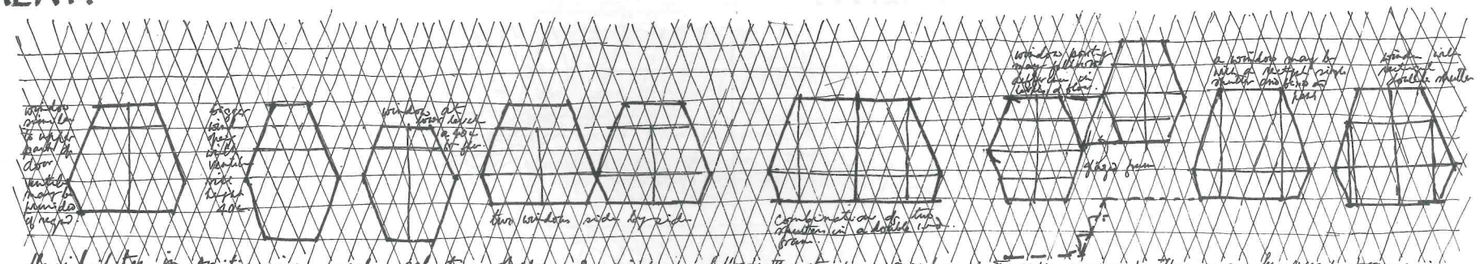


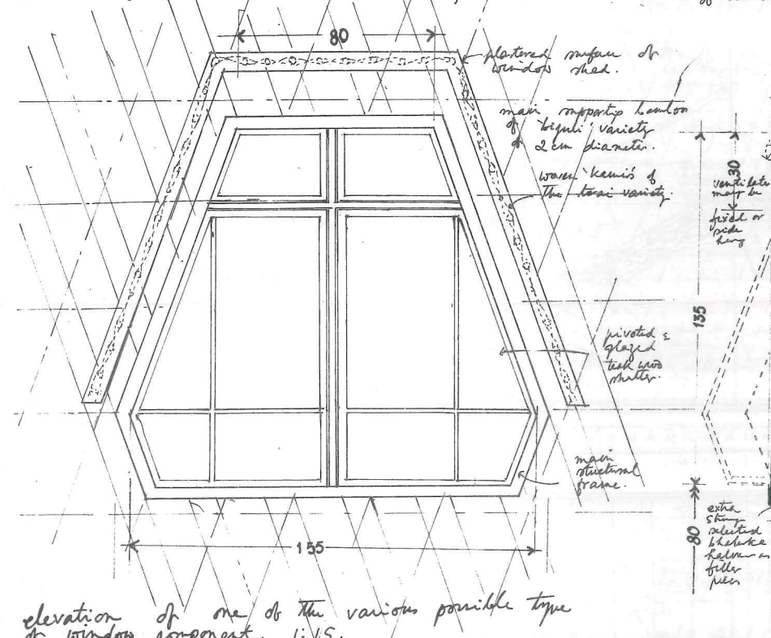


Detail at door jamb at x 1:2

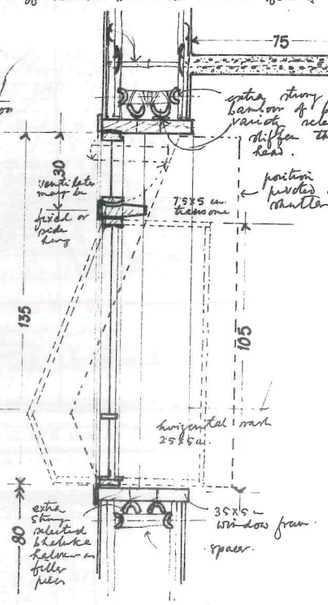
DERIVATION OF THE SYSTEM.
WINDOW COMPONENT.

POSITIONING AND SHAPING OF WINDOWS MAY BE DONE IN VARIOUS WAYS FOLLOWING THE STRUCTURE OF THE WALL COMPONENT. OPENING OUT OF THE WALL PART AND THE STRESS MORPHOLOGY IS SIMILAR TO THOSE OF DOOR COMPONENT. INSTALLATION OF WINDOW FRAME MAY BE DONE AS THE DOOR FRAME IS DONE. ONE OF THE VARIOUS WINDOWS POSSIBLE IS SHOWN IN THE DRAWINGS.



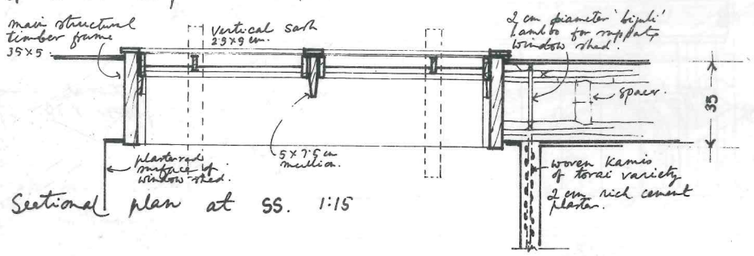


elevation of one of the various possible type of window component. 1:15.



Section at RR 1:15.

Detail of typical arrangement of supporting cantilevers of window shed.

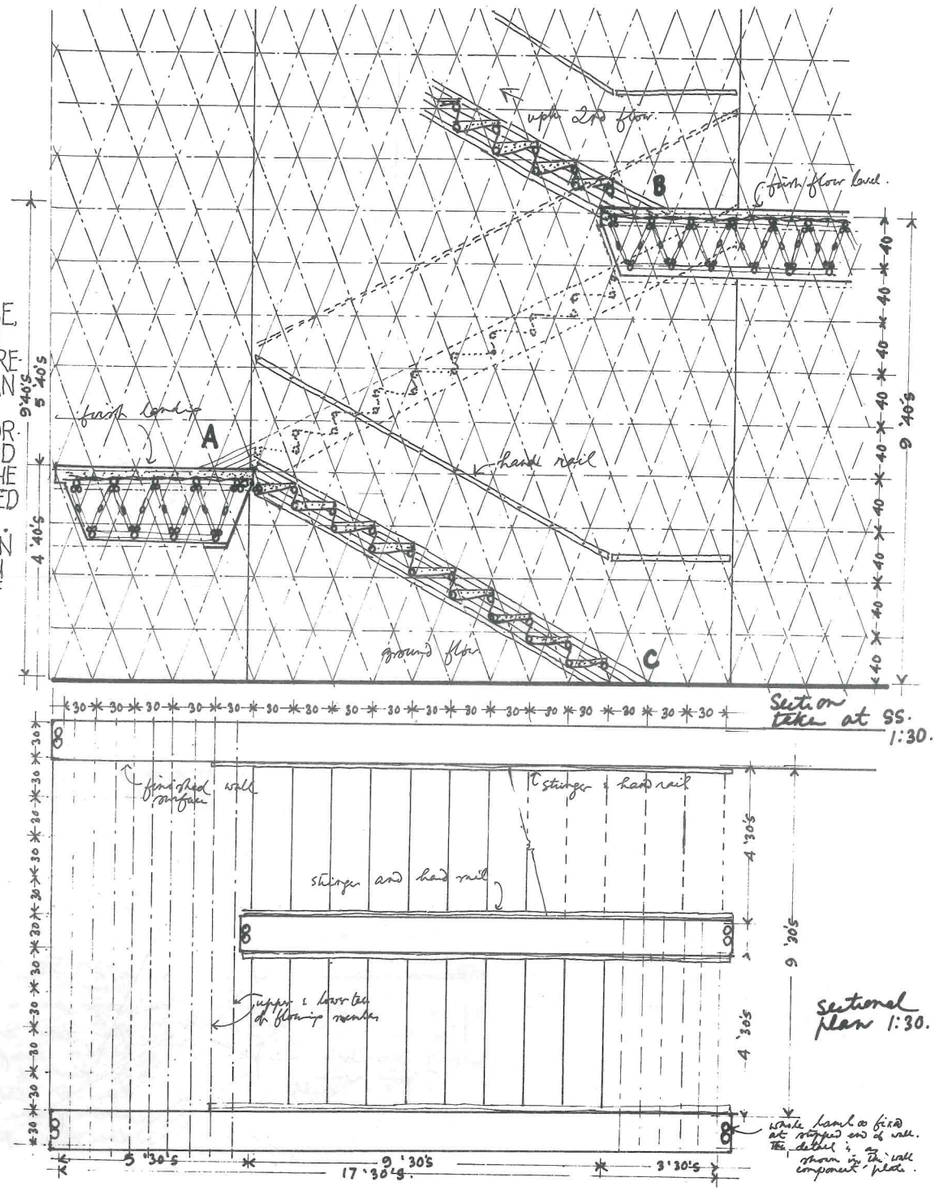


Sectional plan at SS. 1:15

preparation of the surface ground at window jamb for fixing of the window frame may be done in a similar way as is described in the installation of door frame. The door and window frames may be replaced with bamboo reinforced precast concrete frame since it forms a part of the structure of the wall component and it has to take certain amount of stresses. designing of such frame may be done in regular method of designing of B.K.C.C.

DERIVATION OF THE SYSTEM.
STAIRCASE COMPONENT.

IN PLANNING A STAIRCASE, THE FLOOR HEIGHT DIVISION OF FLIGTHS ADJUSTING TREAD A RISERS ARE IMPORTANT. SINCE IN THIS SYSTEM THE FLOOR HEIGHTS AND HORIZONTAL PLANNIG IS GUIDED BY MODULOR DIMENSIONS THE SAME ARE TO BE CONSIDERED IN PLANNING A STAIR CASE. IN THE DRAWING IS SHOWN A STAIR CASE PLANNED ON THE BASIS OF MODULE OF THIS SYSTEM.



Modulor planning of the Staircase —

Since the whole of the building planing system is based on the horizontal module of 30 cm and vertical module of 40 cm while placing & deciding flight heights of staircase the same has to be considered for structural junctions.

division of the flight height shall therefore be guided by the vertical module of 40 cm. Now for a staircase for total clear height between two floor surfaces is 9 '40's then the flight height may be 5 and 4 or 4 and 5 of '40's. Therefor the risers of the floor flight of the steps shall depend on this no of vertical module. For 8 '40's of floor height the flight of staircase may be divided equally in 4 '40's. in each flight. In this case the landing shall be at the middle height of 4 '40's. The height module being '30' and the tread size being same with it the tread division falls in the modular grid system.

Now, the ultimate clear dimensions may be found out by calculations. for example clear width of a stair if wall placed a 4 '40's will be equal to $4 \times 30 -$ (both side plaster thickness + stringer thickness)

$= 120 - (2 \times 2.5 + 15\ cm)$

$= 120 - 5 + 15$

$= 120 - 20 = 100\ cm.$

and for landing floor width here the horizontal module is considered since the dimension considered are horizontal. $= 4 \times 30 +$ both side projection.

$= 4 \times 30 + 2 \times 15.$

$= 120 + 30$

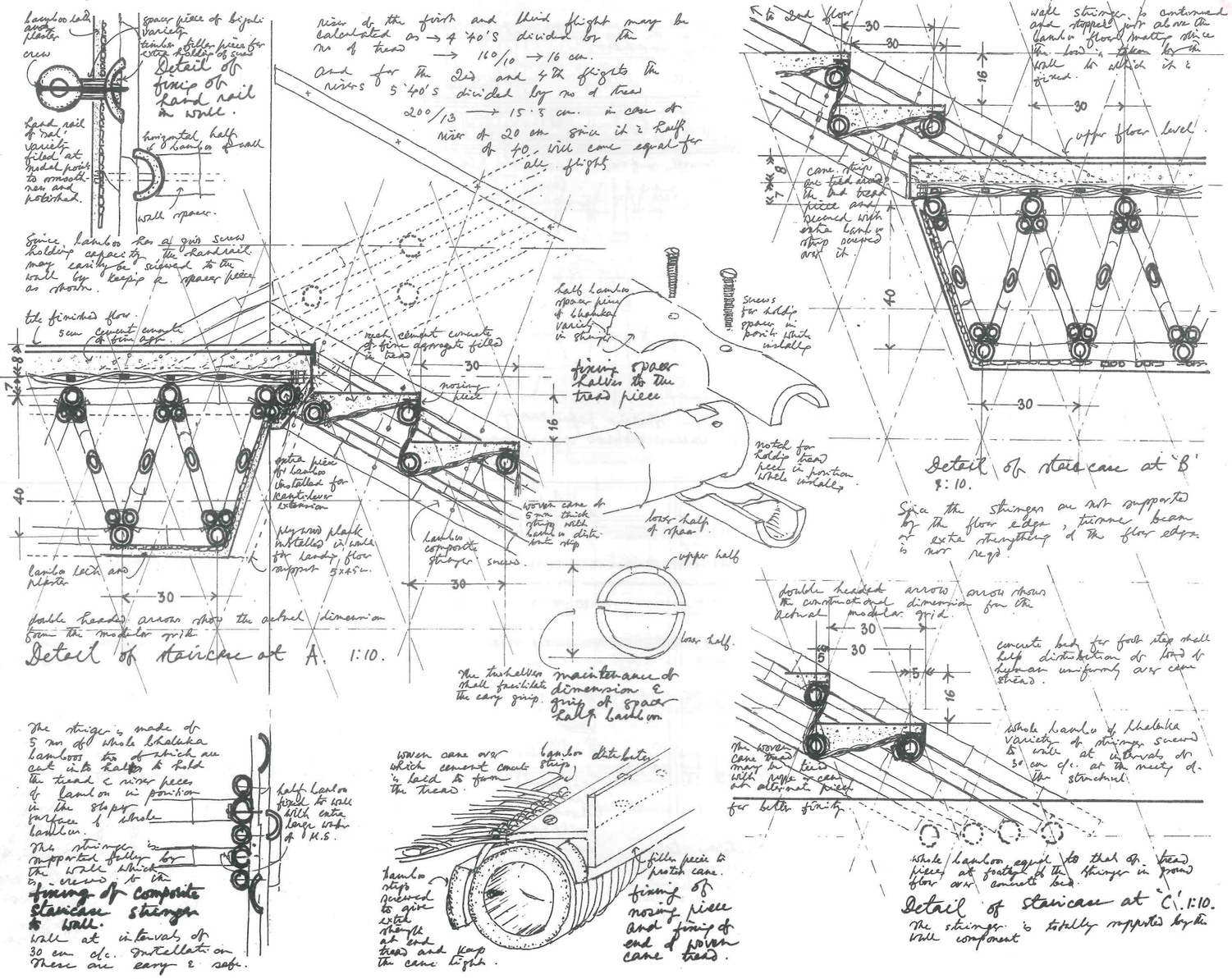
$= 150\ cm.$

tread dimension being '30', it comes in the horizontal planning module. Both rise, if it is $\frac{1}{3}$ of 40 or $\frac{1}{2}$ of 40, will come in the vertical module of planning (ie 13·3 or 20 cm rise) both ultimate flight height shall always be in a module of 40.

In the drawing is shown a staircase planning, vertical height between floor surfaces of which is 9 '40's. Total landing width of 4 '30's + 2 × ½ '40's overhang the total longer side of the staircase space becomes 17 '30's. First landing height is taken at 4 '40's.

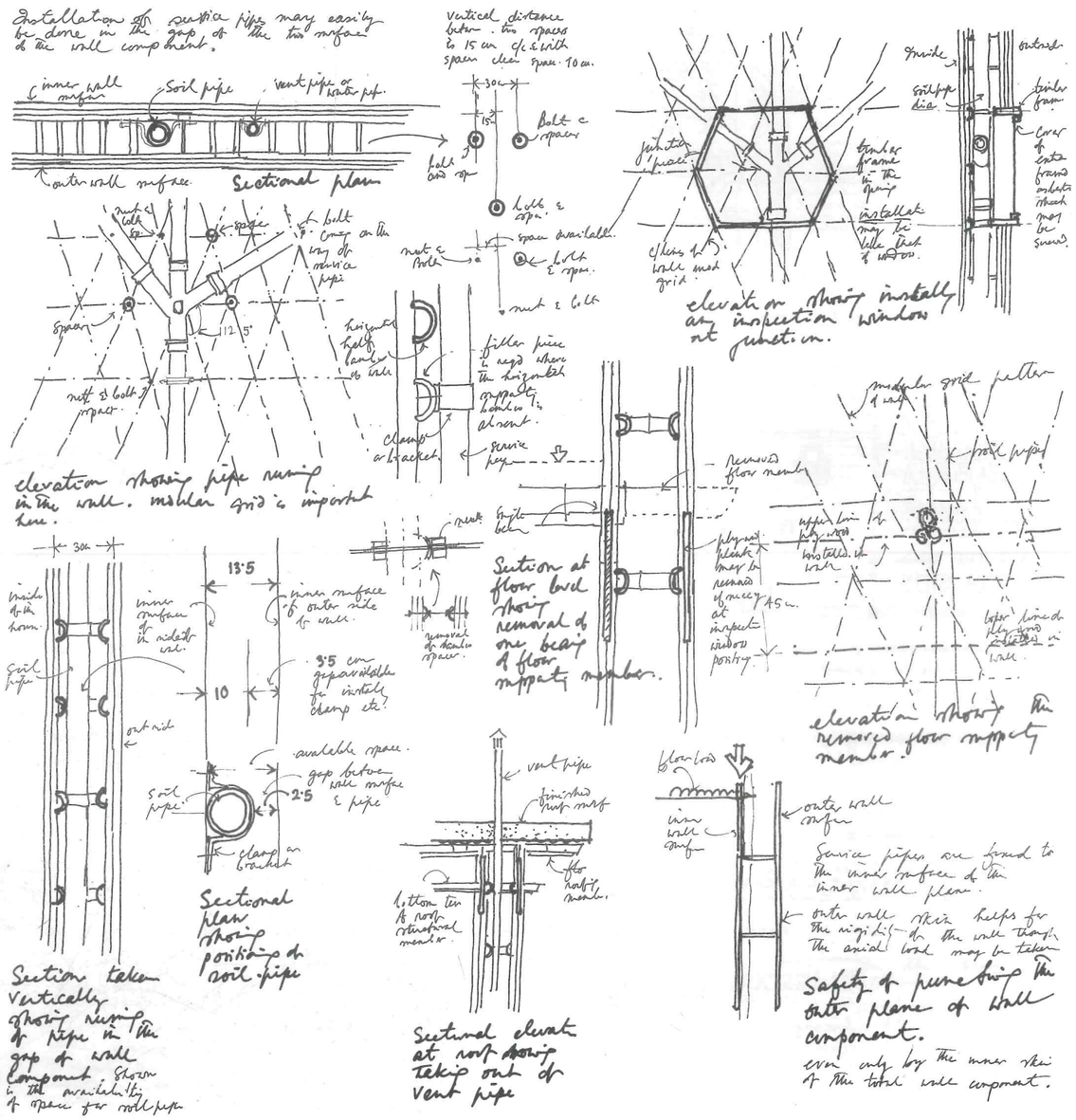
DERIVATION OF THE SYSTEM.
STAIRCASE COMPONENT.

SHOWIN IN THE DRAWINGS ARE CONSTRUCTIONAL DETAILS OF THE STAIR CASE COMPONENT. POSITIONING AND CONTROLING OF DIMENSIONS OF THE VARIOUS PARTS WITH RESPECT TO THE MODULOR GRID IS IMPORTANT. CANE BEING HIGHLY TENSILE AND FLEXIBLE HAS BEEN USED TO FORM THE STEPS OVER WHICH CONCRETE IS POURED FOR LOAD DISTRIBUTION TAKING THE WEAR AND TEAR OF FOOT STEPS.



DERIVATION OF THE SYSTEM.
INSTALLATION OF SERVICE PIPES.

INSTALLATION OF SERVICE PIPES MAY BE DONE INSIDE THE WALL COMPONENT OR IT MAY BE DONE IN THE EXPOSED METHOD. ADVANTAGE OF THE HOLLOW OF THE WALL MAY BE TAKEN AND INSTALLATION MAY BE DONE CONCEALED IN IT. METHOD AND SAFETY OF THE SAME ARE SHOWN IN THE DRAWINGS.



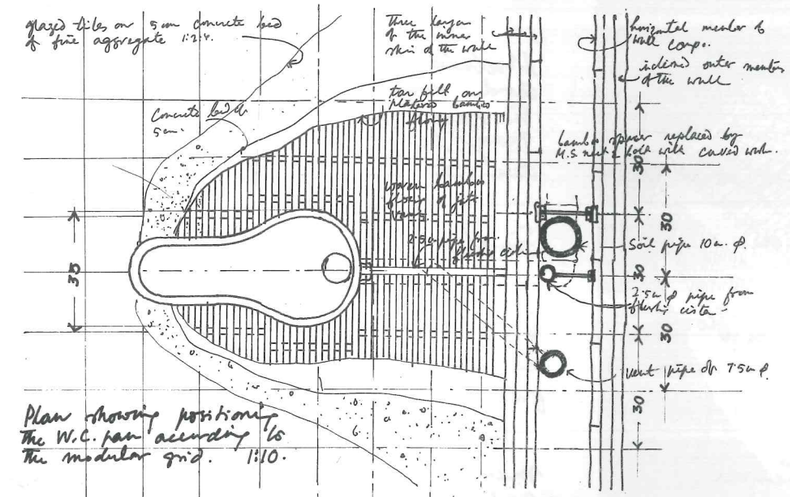
installing of pipes — Service pipes i.e. soil pipe, waste pipe, vent pipe and water pipes may easily be installed in the gap available between the two skin of the total wall component. In case of non load bearing wall installation of these pipes are very easy and safe. But in case of installation inside the load bearing wall component certain measures are to be taken. The space available is more than enough for vent pipes, water pipe and waste pipe since diameter of these are smaller though theoretically we get exactly 10 cm clear vertical space between two spacers in the practical work the space needed is more for adjustment clamps, brackets etc. therefore to make room for the same the metal spacer may be replaced by two washers & nuts thus allowing vertical 4 cm of space. therefore total space available vertically is 14 cm therefore a soil pipe of 10 cm diameter may easily be installed. Spacer which comes exactly on the centre line of the pipes (in case it happens) may be removed.

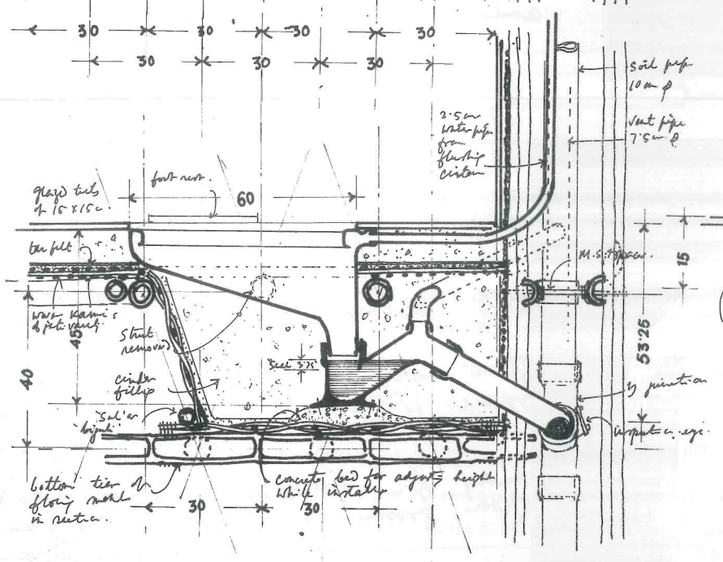
Safety of penetrating the outer skin of wall — Refering back to the design of the load bearing wall component, which is common between two floors, one may see that the actual load of floor etc may be taken of one skin of the total wall component when the wall is an end wall or outer wall. Therefore puncturing of the outer skin is more safe than cutting out the door and window openings. Therefore incase of installing an inspection window the skin may easily be penetrated and for the rigidity lost a timber frame like those of door & window may be installed and covered with a gravel asbestos lid which may be screwed to the frame.

DERIVATION OF THE SYSTEM.

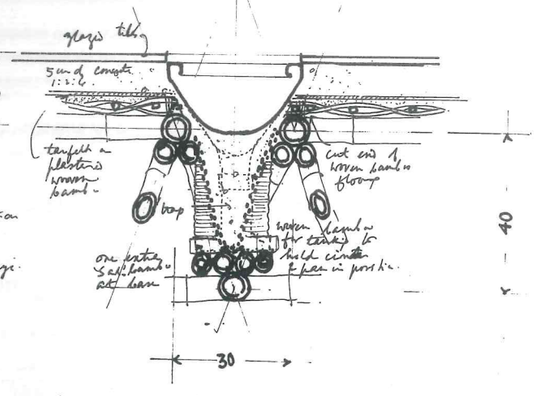
INSTALLATIONS OF W.C., URINAL, WASH BASIN ETC.

INDIAN TYPE WATER CLOSET MAY BE INSTALLED AS SHOWN. FOR THE PURPOSE ADVANTAGE OF THE FLOOR DEPTH IS TAKEN. COMODE TYPE W.C. MAYBE INSTALLED IN THE USUAL WAY OVER THE CONRETE BED OF THE FLOOR. FIXING OF BRACKETS FOR INSTALLING URINAL & WASH BASINS MAY DONE BY SCREWS DIRECTLY OR INDIRECTLY TO THE WALL MEMBERS.





Sectional elevation at PP showing the positions in the floor. 1:10.



Sectional elevation at QQ. 1:10.

W.C. pan Indian type — This installation may be done easily as shown in the detail drawing of the same. In this case the space between the top & bottom tiers of the floor is used. Total depth upto of the pan with the trap is 45 cm. Top to top surface of the flooring members is 40 cm. Therefore this plus the floor thickness of 13.25 cm gives a depth of 53.25 cm. Therefore the system may be easily installed in the floor depth. For this purpose one strip of the top tier flooring member is removed and in the gap the pan is installed. Therefore it is necessary to put the pan always parrellel to the main flooring members. But if it required to have the pan at an angle to these members the same may be done by lifting up the whole system for the main floor. The bamboo flooring mat may easily be cut out and in the trimmed edge pieces of distempered bamboo may be installed. Extra water proofing is done by putting a ten felt cutting on plaster filled bamboo floor and over this cement concrete of 5 cm is laid. Finally the floor finishing may be done like any other brick flooring material. One sides of the wall glazed tile dado may be done on bamboo lath plastered surface. Since there is gap between the plaster surface and the 2nd tier of the wall members the soil water pipe installation may be easily concealed in it.

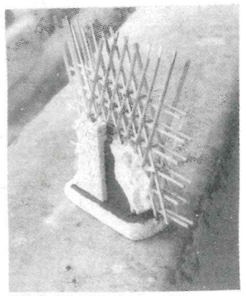
Installation of Comode (European type) urinal and wash basin —

Comode type W.C. pan may easily be done in the conventional way over the concrete bed.

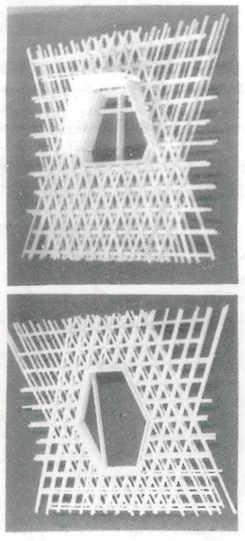
Brackets for installing wash basins may easily be screwed to the bamboo of the wall component. For adjustment of height extra vertical members may be tied or bolted to the diagonal members of the wall surface and over these other fixtures like mirror etc also may be installed safely & easily.

Bathing shower may be fixed to the battens of the upper floor or roof. This may be done easily inside the floor gap.

DERIVATION OF THE SYSTEM.
LIMITATIONS OF THE SYSTEM.



THE SYSTEM THUS DERIVED SHALL HAVE CERTAIN LIMITATIONS OF PLANNING AND CONSTRUCTION OF ITS OWN. GIVEN HERE IS A TABULATION OF THE SAME. THIS SYSTEM OF CONSTRUCTION MAY BE IMPLEMENTED IN ANY RESIDENTIAL BUILDING IN HOT AND HUMID CLIMATIC ZONE.



Planning system.	Modular planning based on horizontal module of 30 cm and vertical module of 40 cm. In case of internal partition the horizontal planning module may be 15 cm since the floor and roof construction allows it due to the two tiers of structural members in them.
Execution.	Simple mechanical method of construction.
Number of floors.	maximum floors shall ground and two upper with the floor height limited to 3·2 M. or 9 vertical modules. In case of floor with double height the maximum no. of floors shall be ground and one upper.
floor height	minimum is 7 vertical module ie 280 cm and maximum limitation is 15 vertical module ie 600 cm.
spanning limit	floor and roof may be spanned upto 510 cm or 17 horizontal module ie 17 '30's.
foundation	continuous concrete foundation or B.B.L.C. beam.
wall system	Bamboo wall of double skin with a hollow in between with height limited to 30 cm when uncovered.
floor system	two tier construction of structural members which span with slats between them. Covering is concrete laid on bamboo matting.
roof system	flat roof with gravel stucco & concrete structure being same with floor.
Sanitary & water pipes installation	may be concealed in the hollow of wall system or open from outside.
Electric installation	may be concealed in wall and roof system in conduits or open wiring.

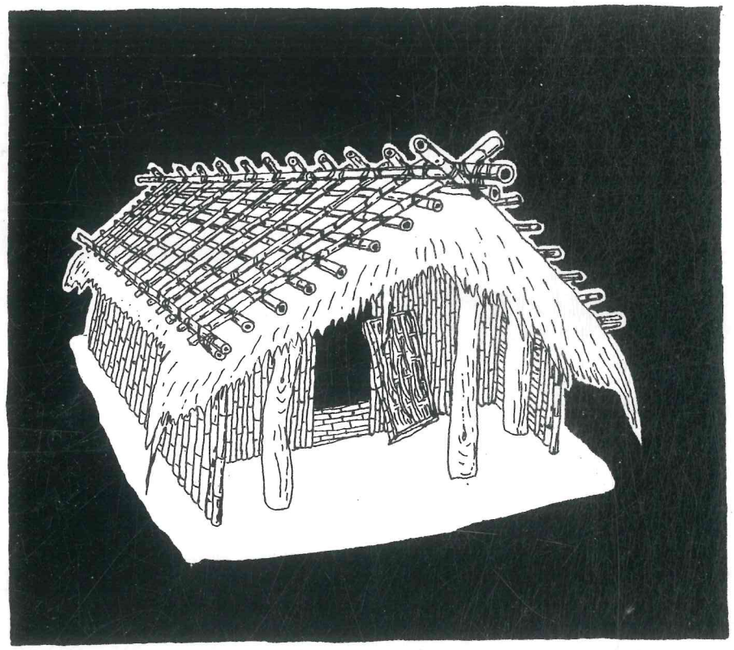
TRADITIONAL BAMBOO HOUSES : A GENERAL OBSERVATION.

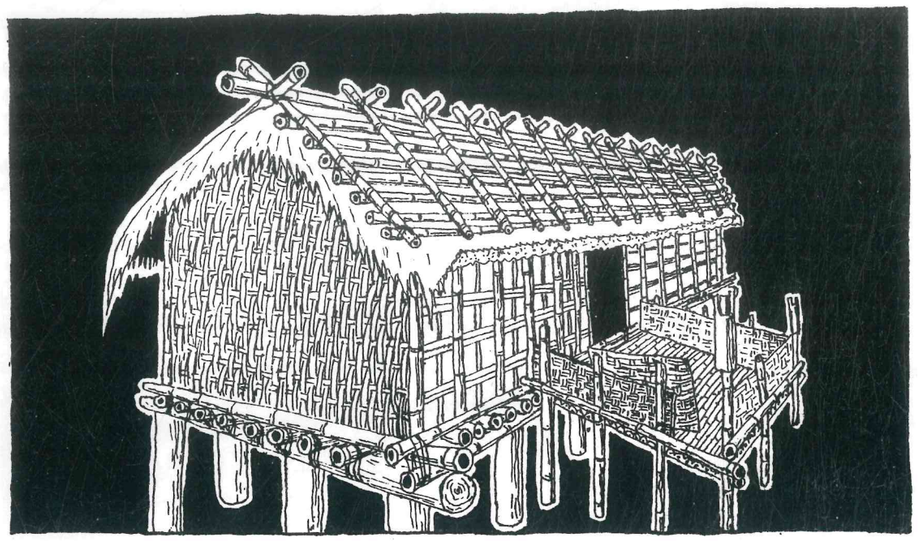
Apart from the few types, shown in little detail, in the previous casestudies the following pages will offer glimpses of different types of traditional house of the North Eastern States of India where the overall construction systems are similar. Irrespective of the states they belong to, the general characteristics can be termed as (a) houses on the plains and (b) those on the hills. The houses on the hills are mostly on the ground with a plinth (and occasionally on low platform and those on the hill slopes are on stilts and a platform in the floor.

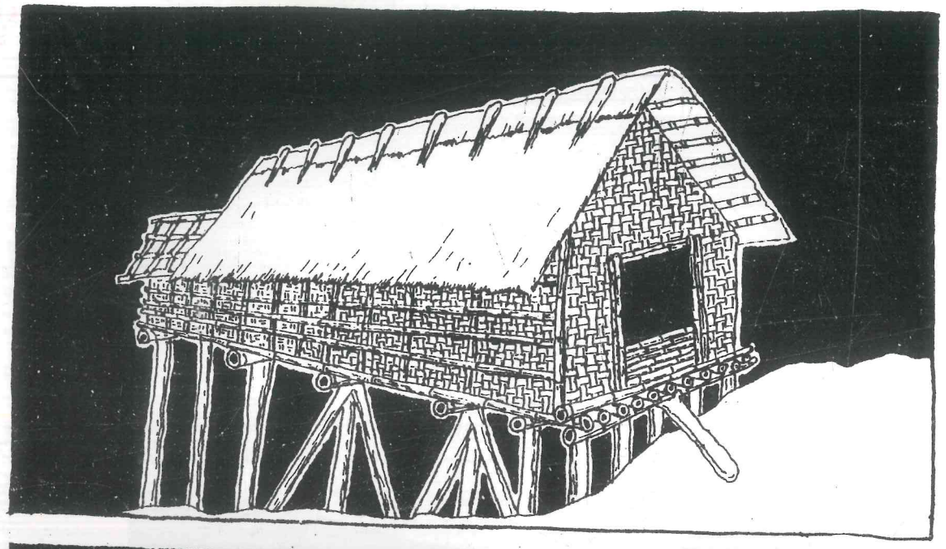
Since the states vary culturally, and also living stylewise, the internal planning of these houses very accordingly. For example in the hill area a house is normally under one roof and compact on a platform whereas in the plains it may be a cluster of roofs spread out around a courtyard to form one house.

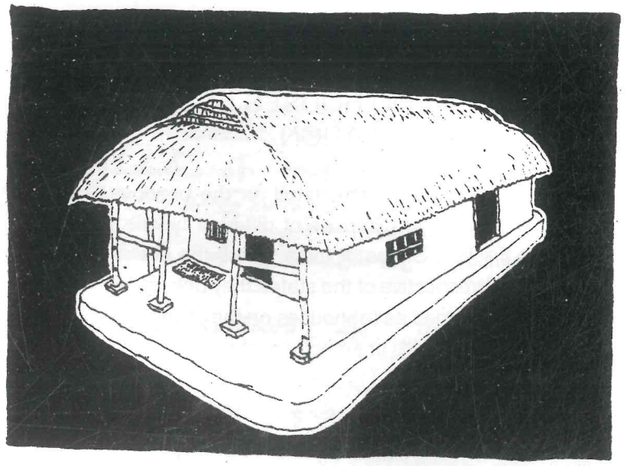
Functionwise also variations are seen in the bamboo structures. In the hills area an watchman's shelter is not on stilts a hill slope but it is a tree top house anchored properly to the branches. A grain store in the plain does not have a plinth but is built upon a low platform with mud plastered floor. The houses of the plains are simpler, technically speaking, and mostly with mud plaster on walls and with mud floor comparatively, the traditional houses of the hilly area show more creativity in detail. Here the walls and floors are exposed bamboo.

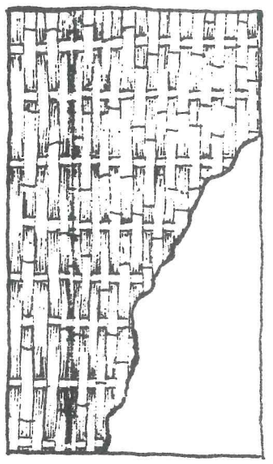
These traditional houses are seen mostly in the remote areas away from the urbanfolk and mostly carry the stamp of poor class. some of these lot who are a little nearer to the urban area and who have the touch of 'Modern things' and better off have gradually started using materials like brick cement & G.I. sheet. It is almost a global phenomenon that if you are a little better off to-day than yesterday. Your psycho is to go for a change. It is a point to ponder whether we need to study a traditional house to bring in better technical details and still be traditional where as the style of traditional living is being given up gradually by the generation.

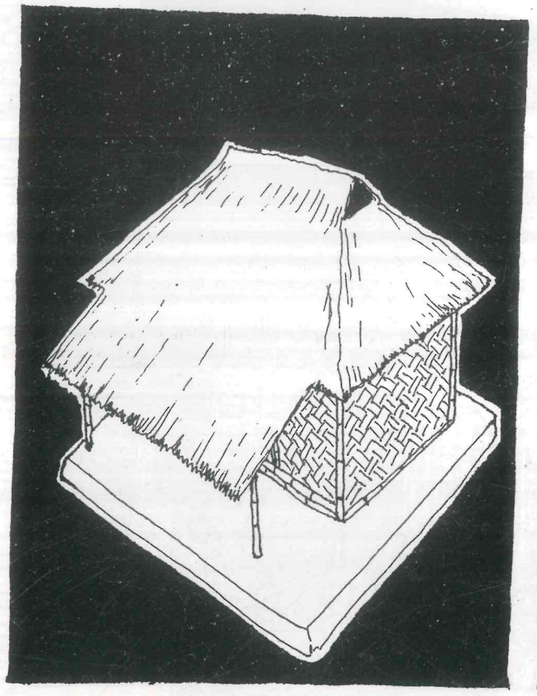


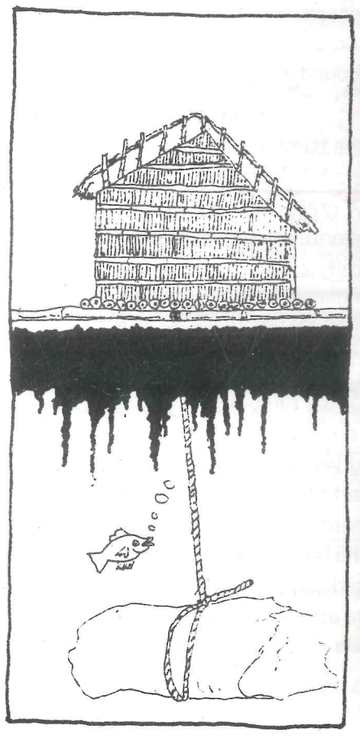


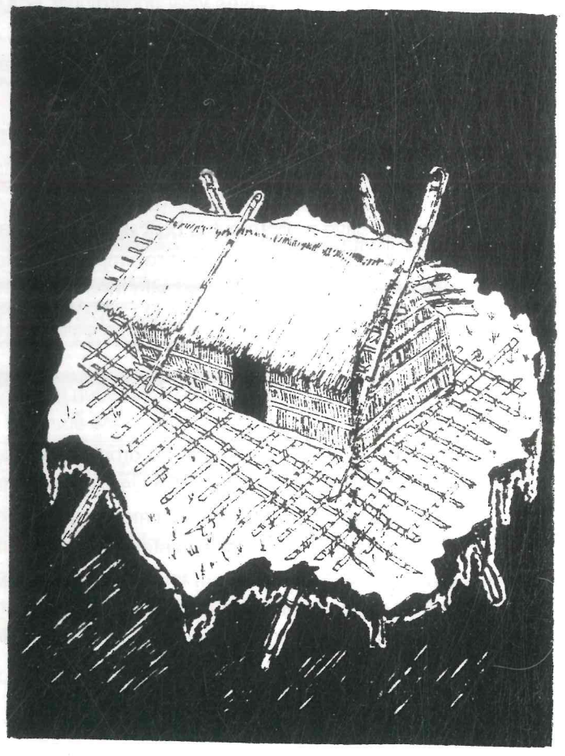


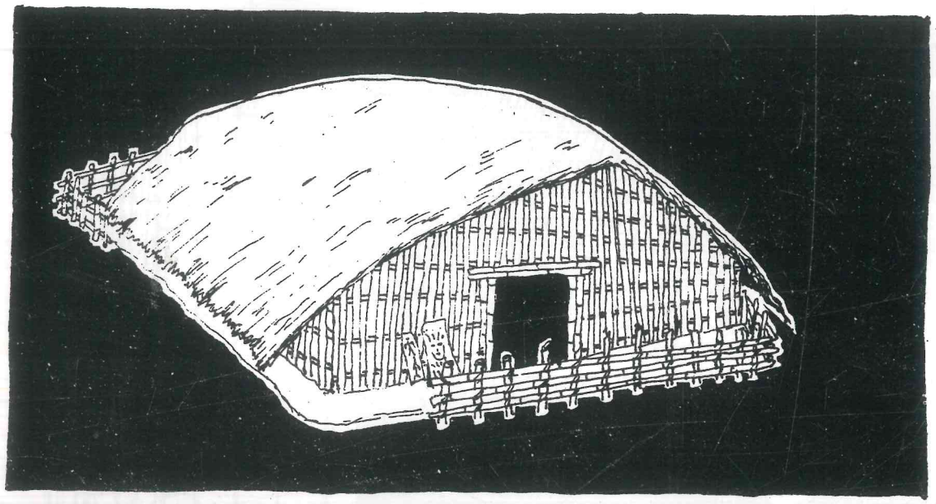


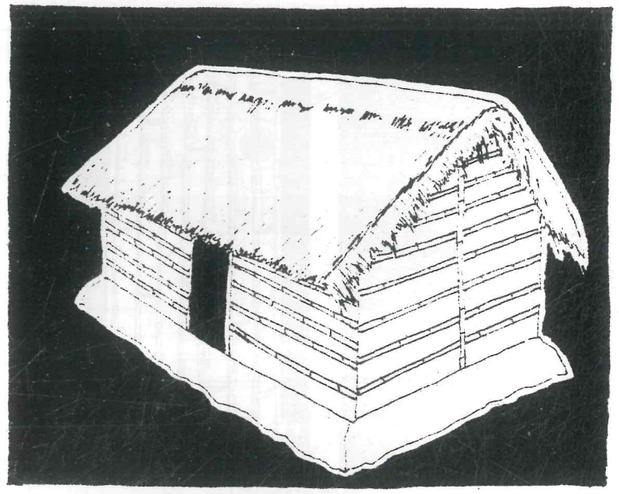


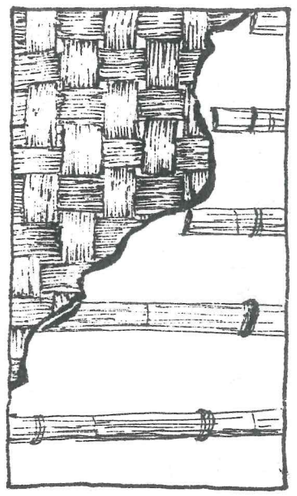


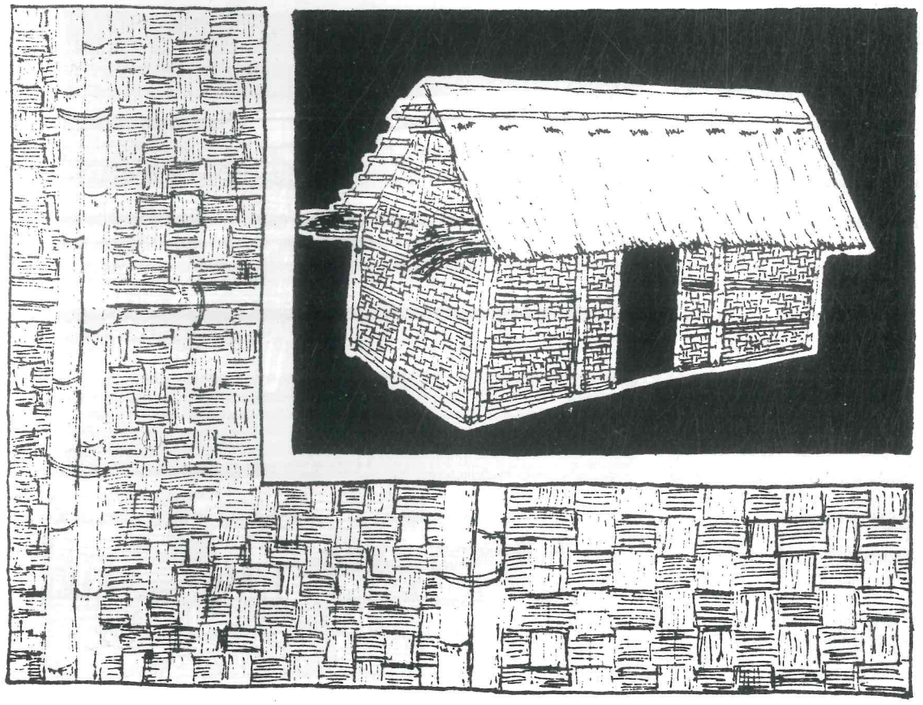


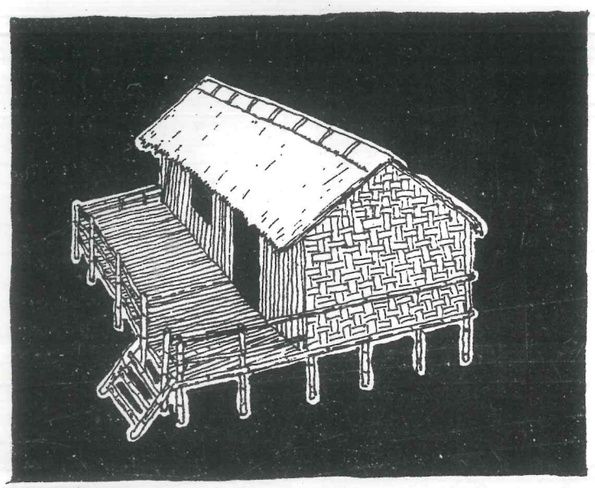


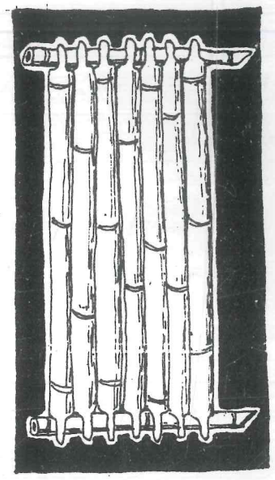


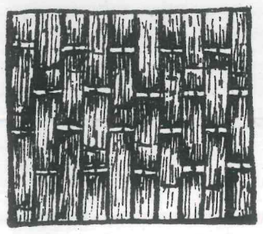


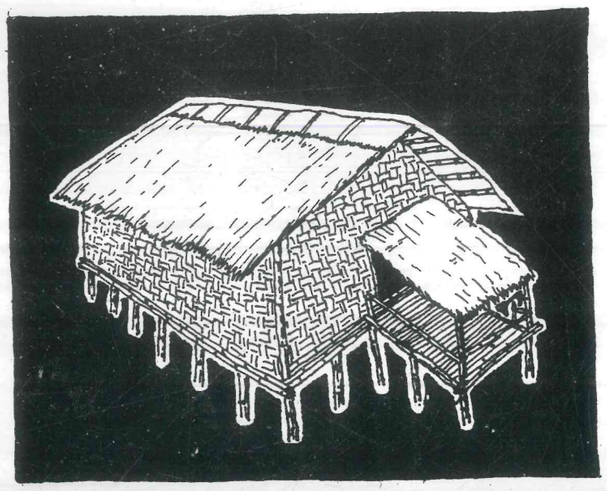


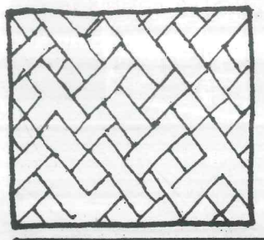


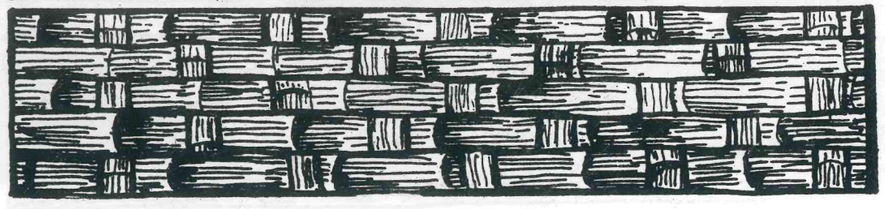


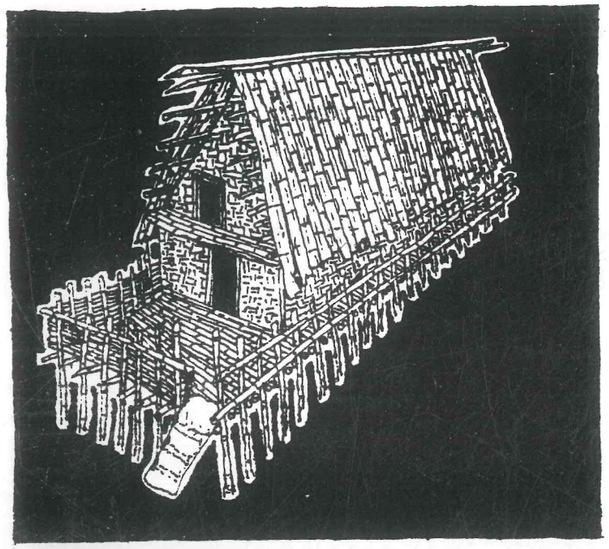


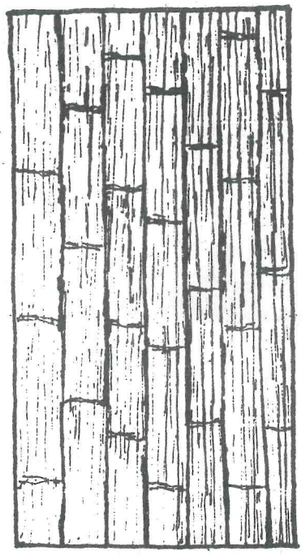


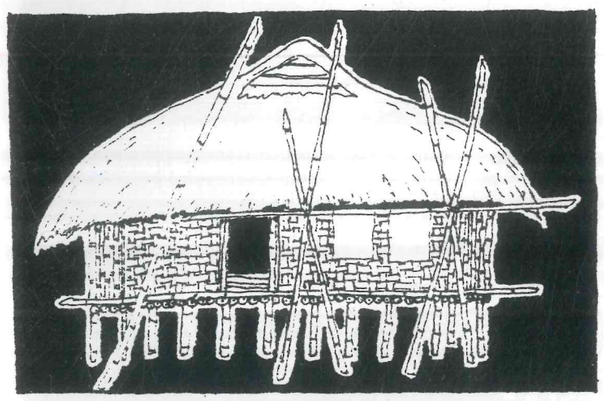


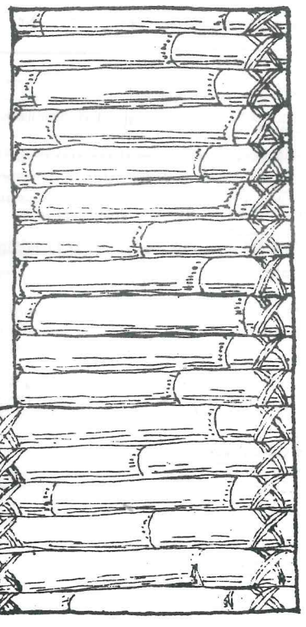


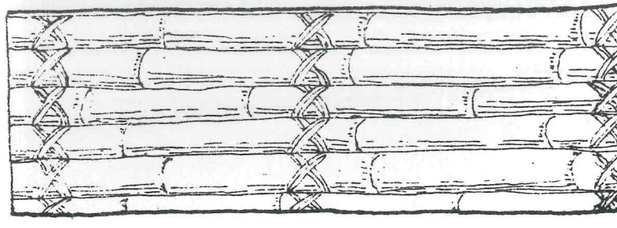










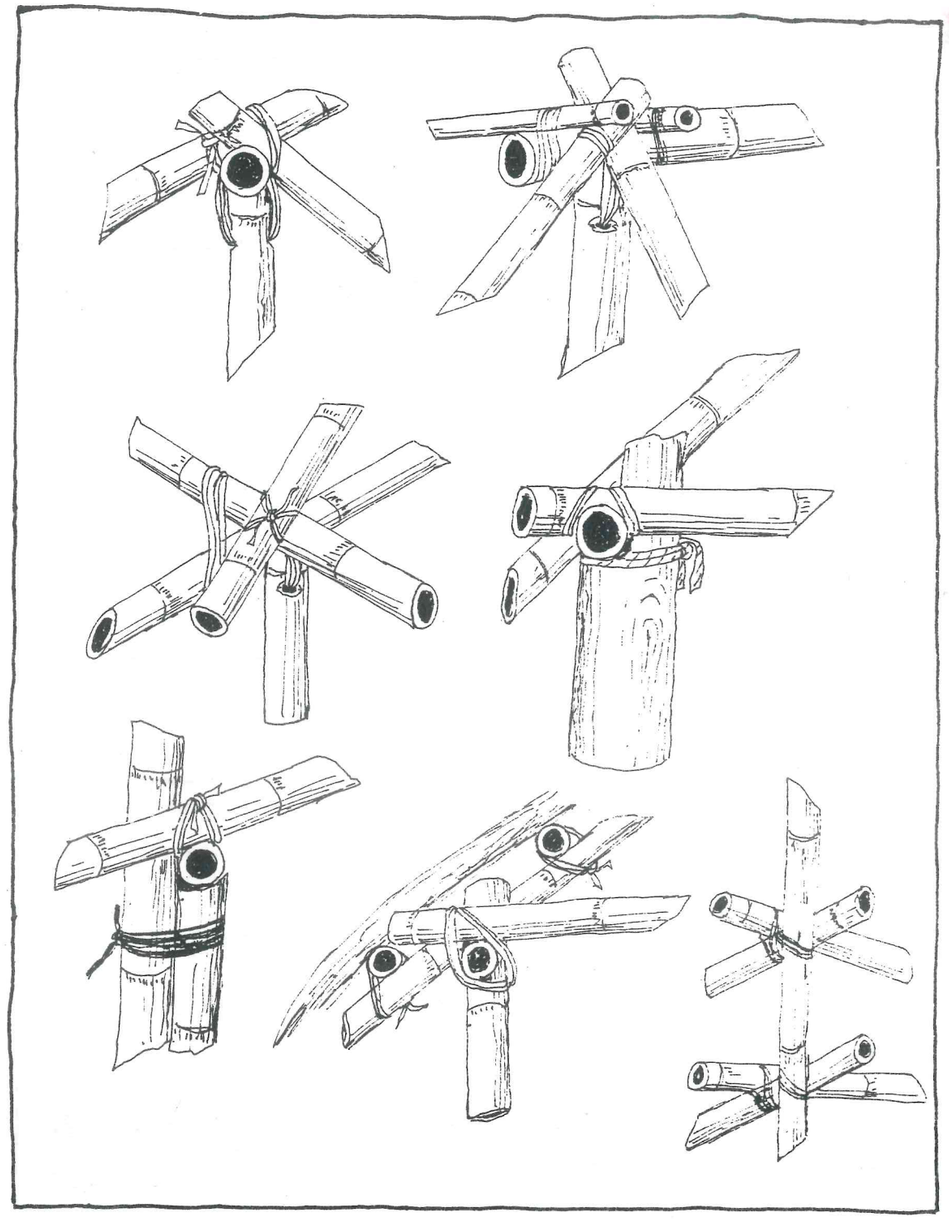


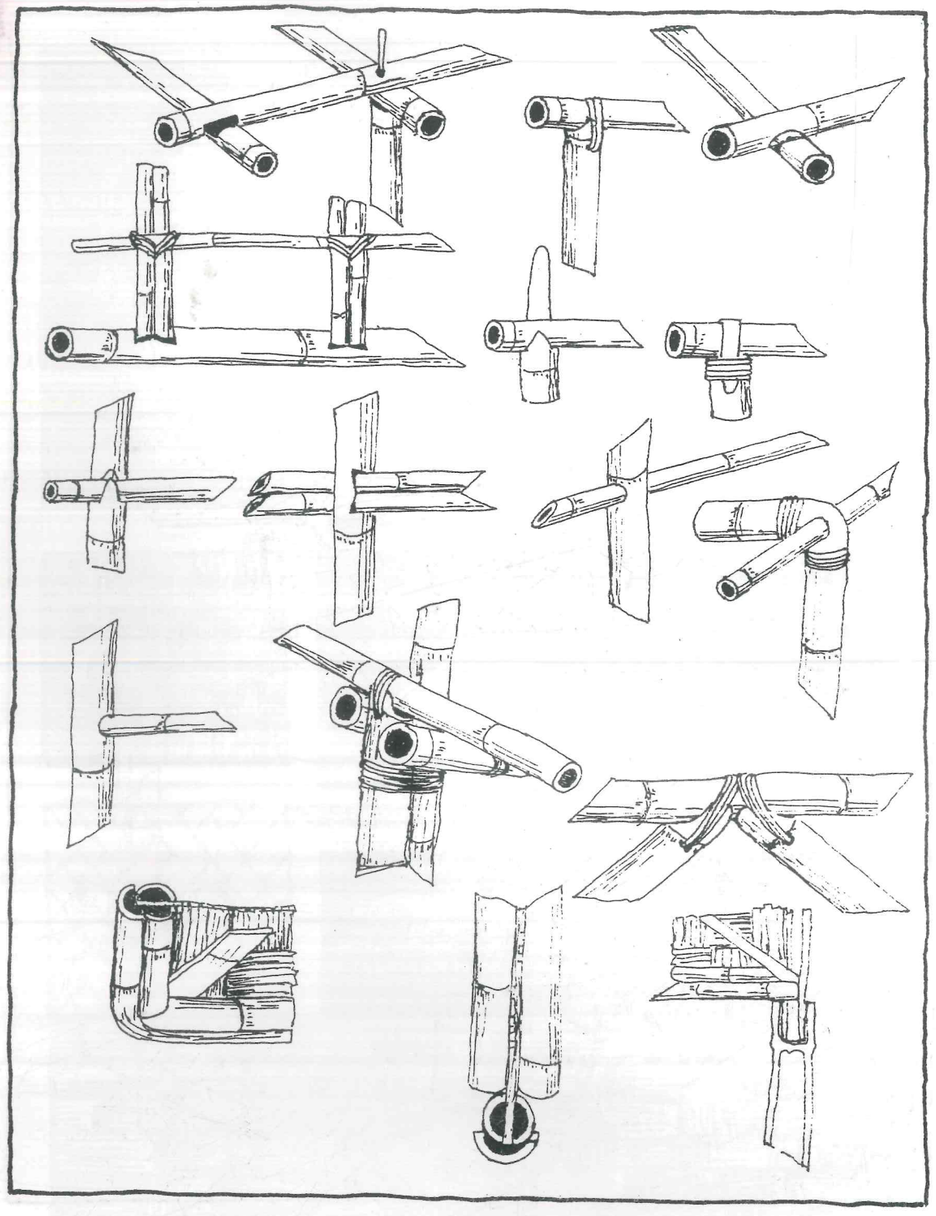
JOINERIES COMMONLY USED

Sketches of joineries that follow are the ones most commonly used in the traditional houses. The reflection of a single tool used can be seen in all the joineries. The angle, the level or the plumb are all by means of judgement and no measuring scales or tapes are used. Hence the overall appearance of a structure or a joint has been the skill of judgement.

As the saying goes -- *'necessity is the mother of invention'* the tradition structure for that matter the joineries must have attained a level of sufficiency in terms of structural safety. security, comfort and functional utility that they have stopped at a certain level of development. In other words the structural adequacy, the comfort level of living therein probably have been just sufficient. Such that further tools for shaping bamboo and disciplinary improvement were uncalled for.

Now it is to be seen what scope do we have to further improve upon them to use in a modern house of to-day. Can we bring in the engineering point of view to have a scientific base for calculationg forces acting upon the joint and for that matter the entire system of structure.

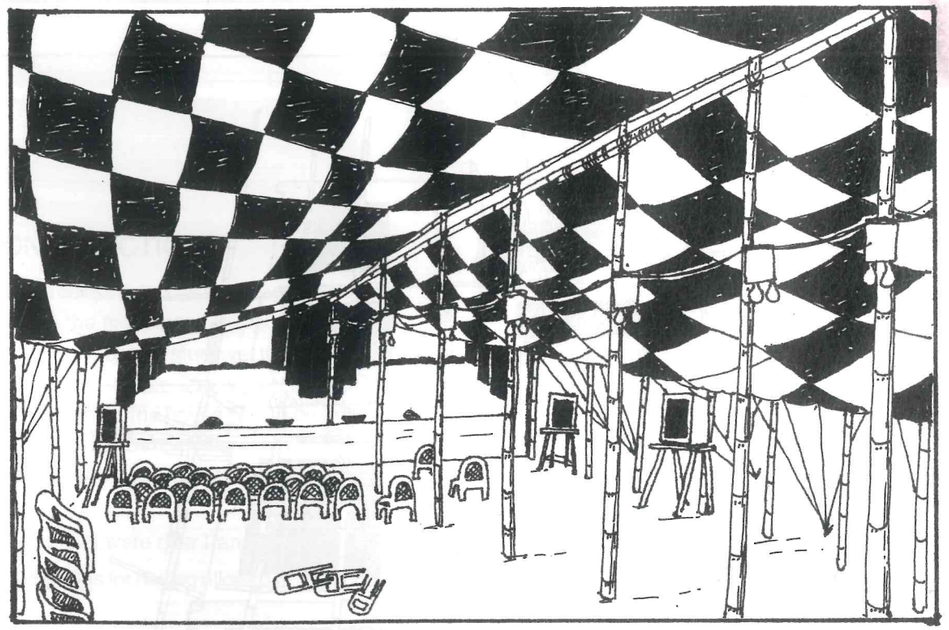


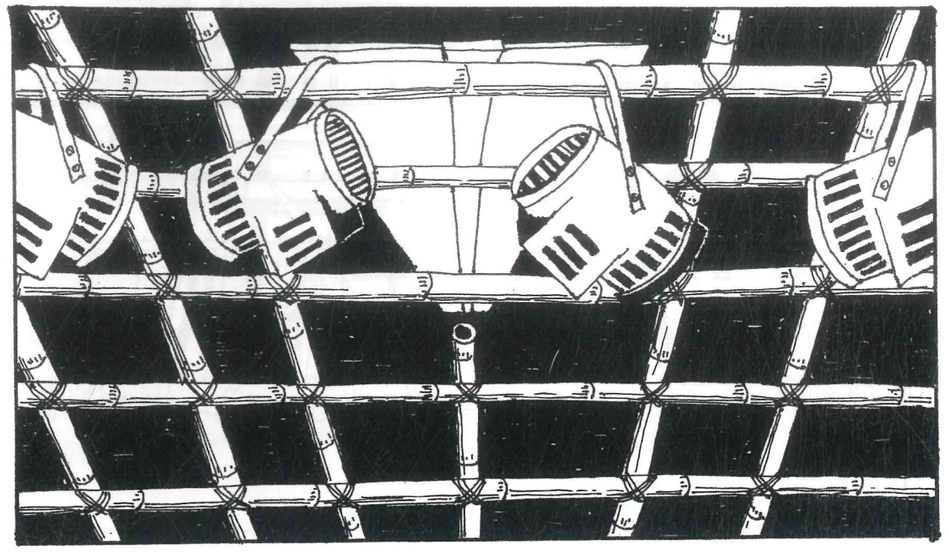


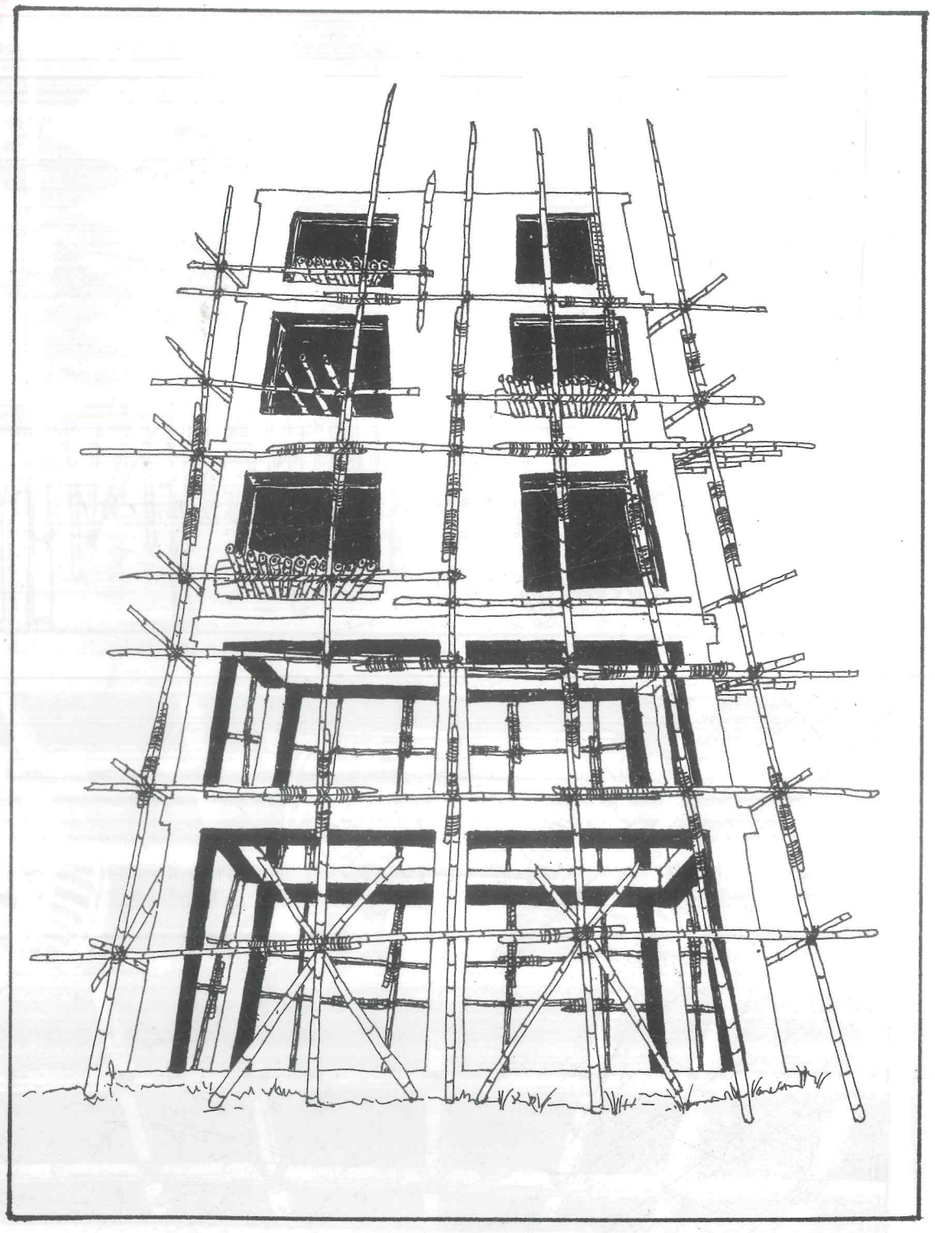
OTHER MULTIPURPOSE USES :

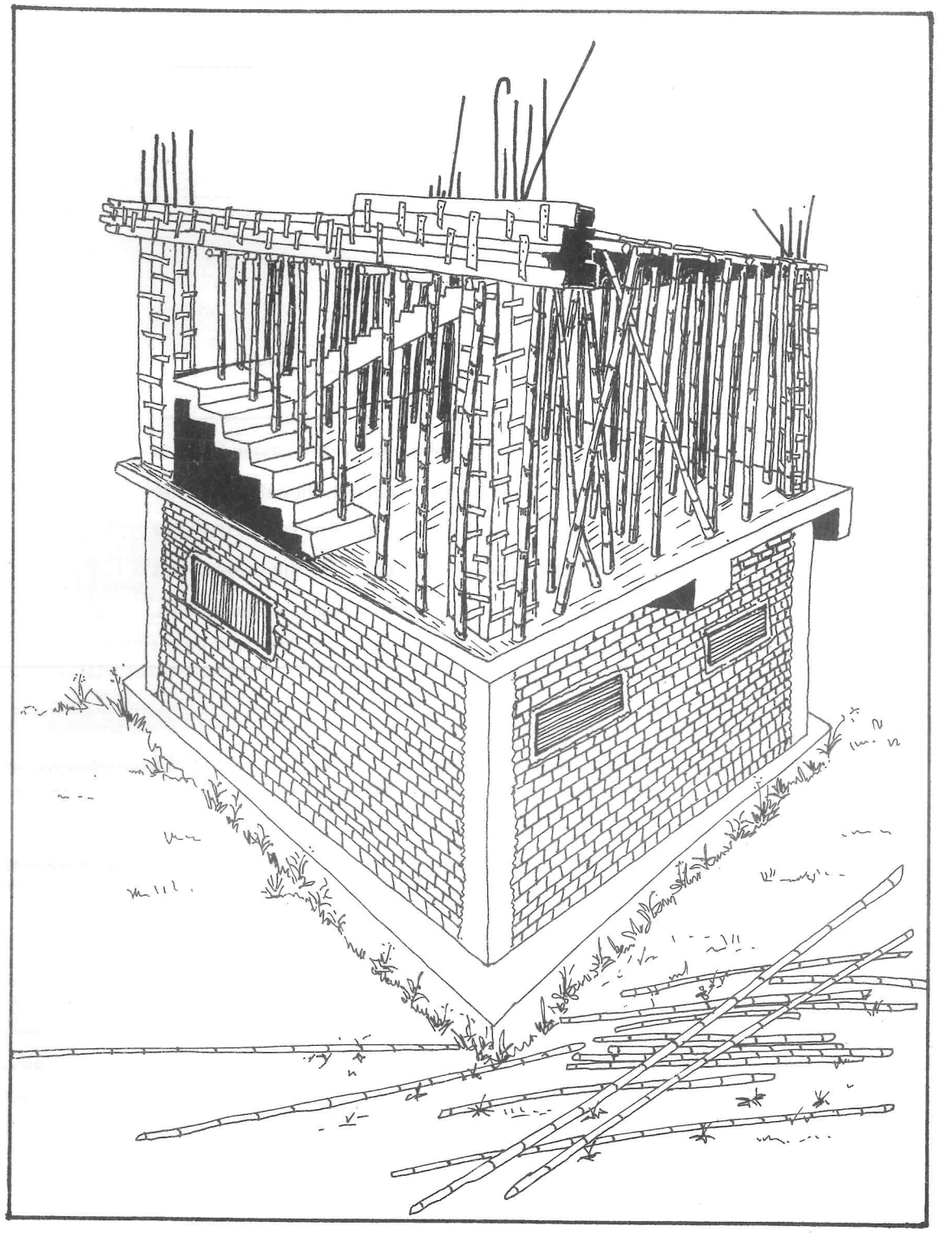
Following sketches will show few other very succesful use of whole bamboos in the field of construction almost unbeaten by other material. Bamboo in this field has established its unavoidable use over the years. The sketches are representative only, and the scale of this use is huge. Some of such uses are seen in building scaffold work, shuttering formwork support for concrete work, large sized temporary shelters/parillions for festive use etc.

High strength-weight ratio, easy workability, low-cost, easy joinery are the factors for prefering bamboo in this feild.









AN EXPERIMENTAL HOUSE : CONSTRUCTION

The following plates will present an experimental house that was constructed 28 years ago (1973) that is approximately 2 years after author's study on bamboo presented in the first part of this book. Though a system of building construction with bamboo had been suggested at the end of said study yet the same could not be adopted for constructing this house for two reasons. One is that the system was not field tested and was not possible for want of fund & technical laboratory facilities. And secondly, the house was to be taken up for construction in parallel with author's professional practice. Thus it had to be simpler without calling for constant supervision of work. The methods was to later on, fit into a system – building with modular planning & pre-feb components.

Bamboo used were not chemically treated but taken from the lot that were river transported.

Author is thankful to his father Suryya Kanta Das and Mother Kunja Das for having allowed to experiment with their only house.

Location :
Bye-Lane 11 West
R.G. Barua Road
Guwahati - 781024
Assam . India.

Note : The documentation was done in 1995, i.e. 22 years after construction.

AN EXPERIMENTAL HOUSE :

BAMBOO AS ONE OF THE BASIC BUILDING MATERIAL

OWNER : MR SURYYA KANTA DAS
LOCATION : BY-LANE 11 WEST ZOO ROAD , GUWAHATI-781024 ASSAM . INDIA

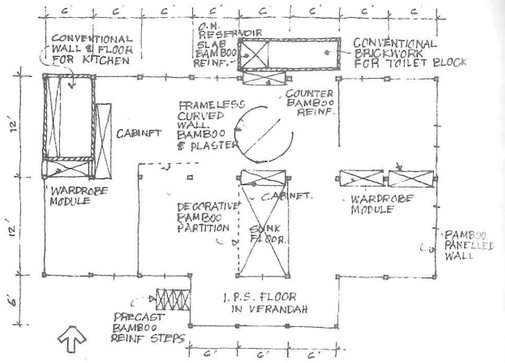
ARCHITECT : BIPUL KR. DAS.

THE NECESSITY OF HAVING A COST EFFECTIVE HOUSE FOR OUR FAMILY AFTER MY FATHER'S RETIREMENT FROM SERVICE IN 1974 GAVE RISE TO THE THOUGHT OF USE OF BAMBOO IN OUR HOUSE . THIS THOUGHT IS ALSO AN AFTERMATH OF MY STUDY ON BAMBOO DONE AT THE TIME OF MY GRADUATION TWO YEARS EARLIER . AND AFTER A SUCCESSFUL EXPERIMENT OF THE ROOF UNIT ON GROUND , THE IDEA CRYSTALISED. THE CONSENT OF MY FATHER TO BUILD THIS EXPERIMENTAL HOUSE WITH HIS LAST SAVINGS WAS VERY VALUABLE TO ME AND WAS A GREAT CHALLENGE TO TAKE UP THIS CALCULATED RISK.

AND NOW (1995), AFTER MORE THAN 22 YEARS OF IT'S CONSTRUCTION , THAT THE EXPERIMENTAL HOUSE STILL EXISTS IS A VERY BIG BOOST FOR ME TO LOOK FORWARD TO A LOT MORE.

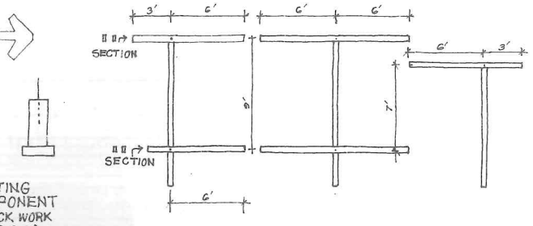
THE HOUSE WAS STARTED IN MID MAY '93 (TWO YEARS AFTER MY GRADUATION) WHEN CEMENT WAS SCARCE. WOOD COMPARATIVELY BEING CHEAPER AND TO CONSUME LESS CEMENT IT WAS DECIDED TO GO FOR A WOODEN FLOORED HOUSE . THE PROJECT GOT STARTED WITH A MERE 7 BAGS OF CEMENT AVAILABLE FOR THE FOOTINGS. THE WORK CONTINUED FOR THE NEXT 7 WEEKS WITHOUT CONSUMPTION OF CEMENT. THEN IT HAD TO BE STOPPED FOR 9 WEEKS FOR WANT OF CEMENT . FINALLY AFTER ANOTHER 12 WEEKS' TIME THE HOUSE WAS COMPLETE FOR OCCUPATION (END OFth JAN.' 74).

ALL THE WOODEN MEMBERS USED , EXCEPTING DOORS, WINDOWS SHUTTERS & FLOOR BOARDS, ARE IN UNDRESSED CONDITION . CONSTRUCTION SYSTEM ADOPTED IS OF PRE-FAB. SYSTEM-BUILT TYPE AND THE PLANNING IS SIMPLE MODULOR GRID TYPE.



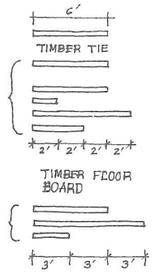
PLANNING IN THE STRUCTURAL GRID OF 6'X 12' (FOR DETAILS REF : NEXT SHEET)

COMPONENTS INTRODUCED FOR THE SYSTEM BUILDING

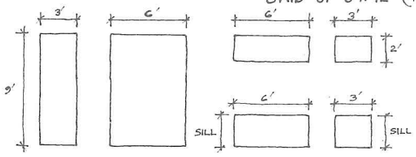


FOOTING COMPONENT (BRICK WORK & P.C.C.)

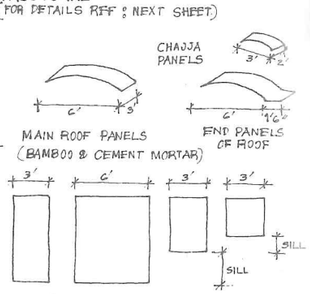
MAIN STRUCTURAL COMPONENTS OF POST & BEAM (WOODEN)



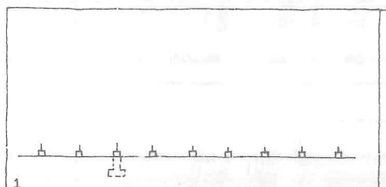
TIMBER WALL FRAMES



BAMBOO & PLASTER WALL PANELS USED (DIMENSIONS GIVEN ARE MODULOR, ACTUAL DIMENSIONS ARE ± JOINTS)

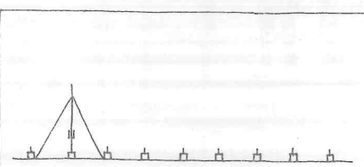


STAGES OF CONSTRUCTION :



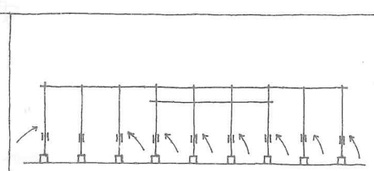
1

BUILDING FOOTING (FOUNDATION) COMPONENT LAID OUT IN 6' x 12' GRID.



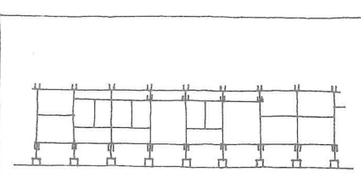
2

ONE BUT THE FIRST ROW OF POST WITH FLOOR BEAMS ERRECTED & SUPPORTED/ PLUMBED BY MEANS OF BAMBOO TRIPOD



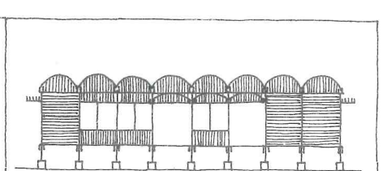
3

ALL ROWS OF POST ERRECTED ONE BY ONE (IN DIRECTIONS SHOWN) TIED UP IN POSITION WITH POST-TIES , TRIPOD REMOVED.



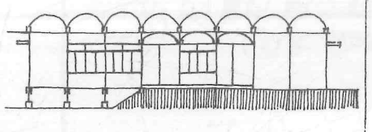
4

ROOF-BEAMS , FLOOR-JOISTS, WALL FRAMES, DOOR/WINDOW / SHED FRAMES FITTED (UP TO THIS STAGE IT TOOK 3 WEEKS TO COMPLETE)



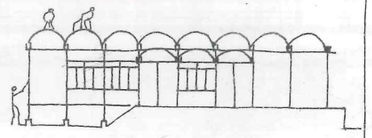
5

SPLIT & STRESSED BAMBOO WOOVEN IN POSITION ON ROOF BEAMS, WALL FRAMES , ROOF OVER HANGS & WINDOW SHEDS.



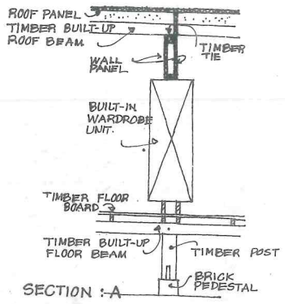
6

MORTAR TOPPING ON ALL WOOVEN BAMBOO SURFACES DONE & DOOR-WINDOW SHUTTERS FITTED (EARTH TERRACING DONE)

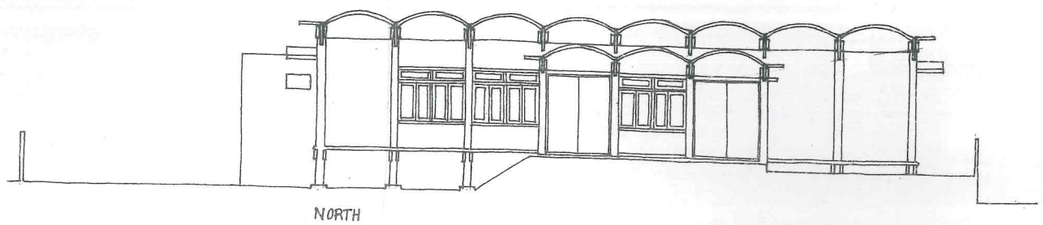


7

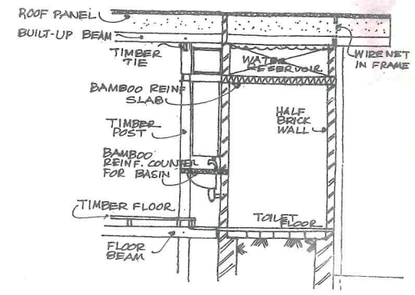
FINISHING OF BUILDING , WATER PROOFING TREATMENT, COLOUR WASH/PAINTING/ GLAZING ETC.



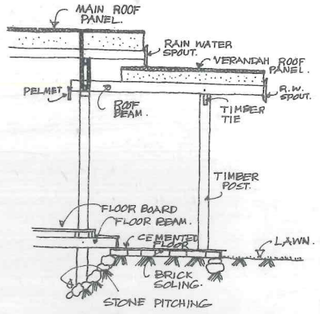
SECTION :-A



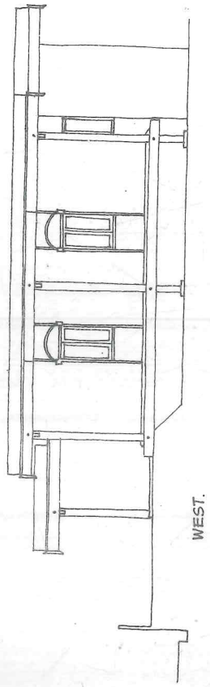
NORTH

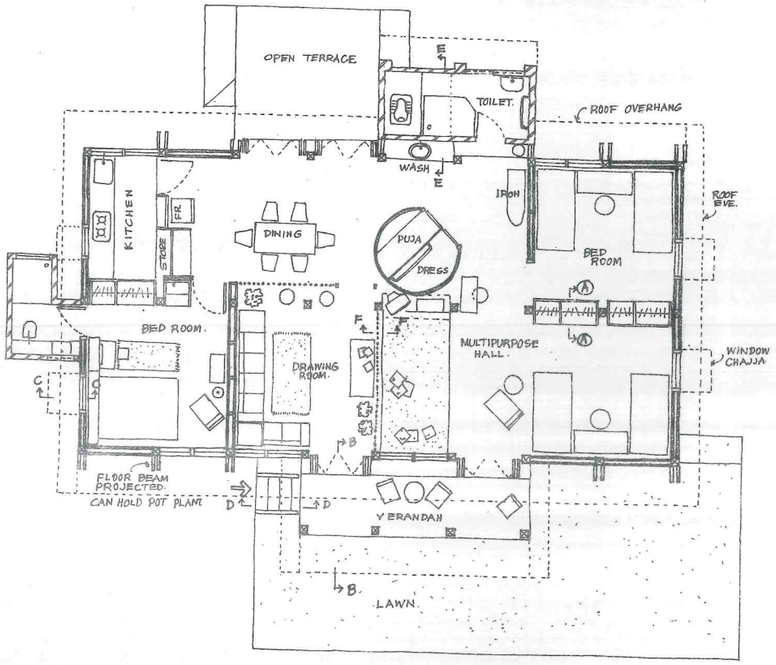


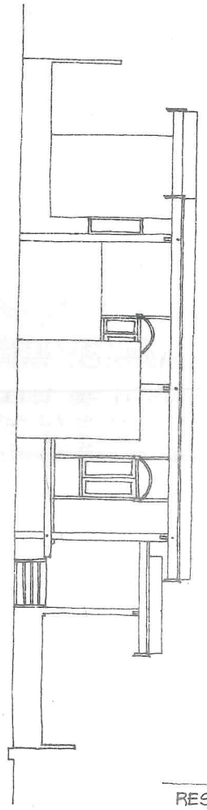
SECTION - E

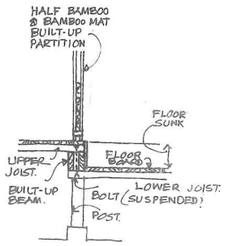


SECTION - B

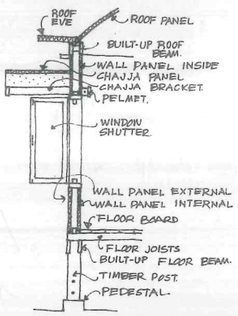




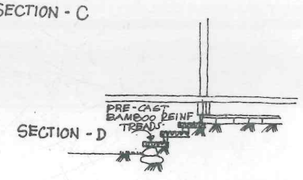




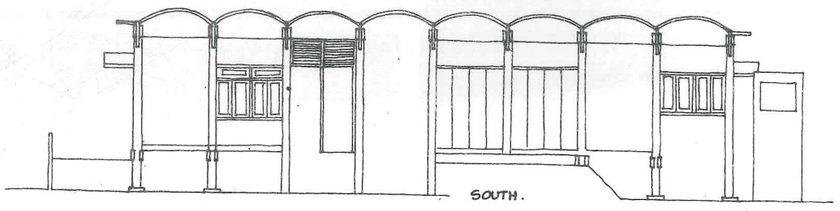
SECTION - F



SECTION - C

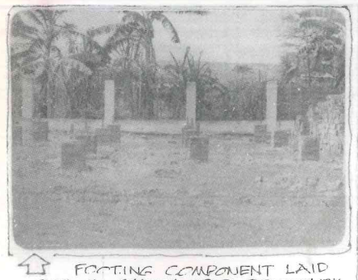


SECTION - D



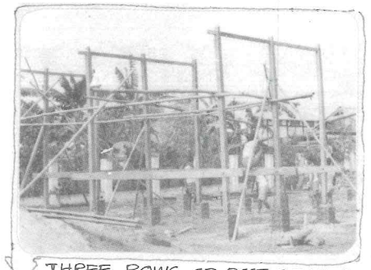
RESIDENCE OF : MR. SURYYA KANTA DAS.
LOCATION : BY-LANE 11 WEST
ZOO ROAD.
GUWAHATI 781 024
ASSAM : INDIA.
CONSTRUCTION : STARTED MID MAY 1973
COMPLETED END JAN 1974.

ARCHITECT : BIPUL KUMAR DAS.



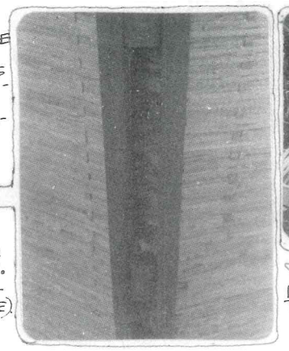
FOOTING COMPONENT LAID OUT IN 6'X12' GRID. BRICKWORK WITH R.C.C. CORE WITH M.S. FLAT HOLD FAST FOR TIMBER POSTS.

ONE BUT THE FIRST ROW OF POST & BEAM COMPONENT BEING LAIDOUT PRIOR TO ERECTION. FIRST STAGE OF FRAMEWORK

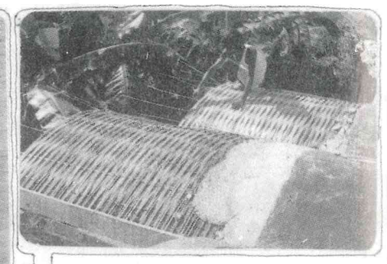


THREE ROWS OF POST-BEAM & TIE SEEN. NOTE TRIPOD SUPPORT TO ONE BUT THE FIRST ROW.

THE ROOF PANEL IN THE MAKING. SPLIT BAMBOO BEING WOVEN IN POSITION. PANELS ARE INTERLOCKED.

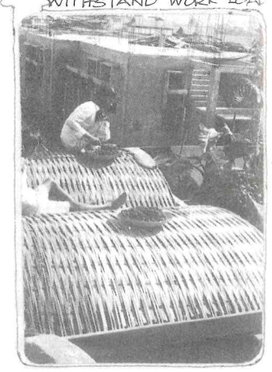


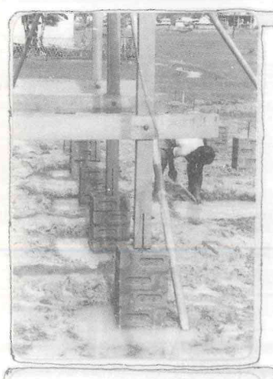
BUILT-UP ROOF BEAM AND INTERLOCKED BAMBOO ROOF PANELS SEEN FROM BELOW. (BEFORE PLASTERING IS DONE)



THE SPLIT BAMBOO WOVEN PANELS CAN TAKE THE LOAD OF THE WORKER.

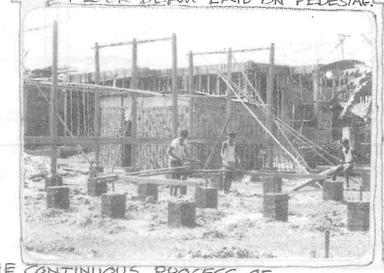
THE SPLIT BAMBOO WOVEN ROOF PANEL IS ITSELF THE FORMWORK AND IT CAN WITHSTAND WORK LOAD





POST-FLOOR BEAM & PEDESTAL SEEN. NOTE SLIT IN POST FOR M.S. FLAT HOLD FAST.

THE CONTINUOUS PROCESS OF ERECTION: ROW OF POST & FLOOR BEAM LAID ON PEDESTAL.



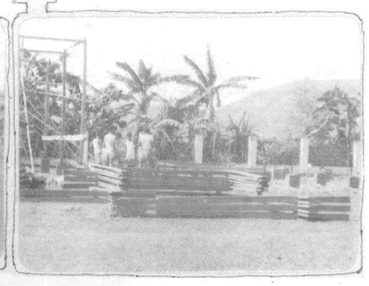
THE CONTINUOUS PROCESS OF ERECTION: POST-TIE & FLOOR BEAM COMPONENTS BEING LIFTED.

THE WINDOW CHAJJA UNIT. TIMBER BRACKET & SPLIT BAMBOO WORK.

THE CHAJJA UNIT IS STRONG ENOUGH TO TAKE THE LOAD OF A PERSON EVEN BEFORE THE CEMENT WORK.

THE CONTINUOUS PROCESS OF ERECTION: POST TIE FIXED.

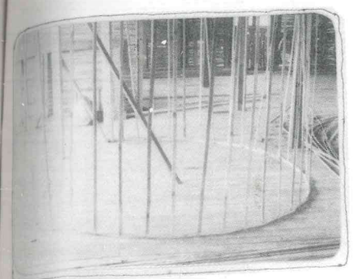
SYSTEM-BUILT PROCESS WAS ADOPTED. PREFABRICATED COMPONENTS OF POST-FLOOR BEAM AND ROOF BEAM COMPONENTS STACKED AT SITE.



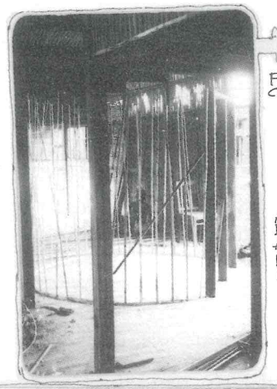
CEMENT-SAND TOPPED ROOF UNIT WITH CONSTRUCTION JOINTS SEEN. NOTE ROOF ENDS FOR PROTECTION OF TIMBER ROOF BEAM FROM RAIN ETC.

ROOF ENDS BEING FINISHED.

FINISHED ROOF, CONSTRUCTION JOINTS SEALED WITH BITUMENOUS COMPOUND.

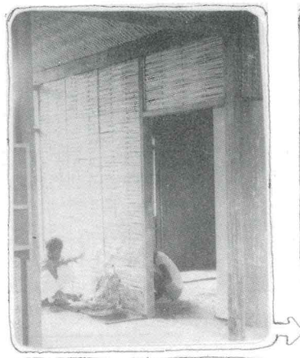


STARTING OF THE FRAMELESS, CURVED AND FREE STANDING BAMBOO WALL FOR A CIRCULAR ROOM.



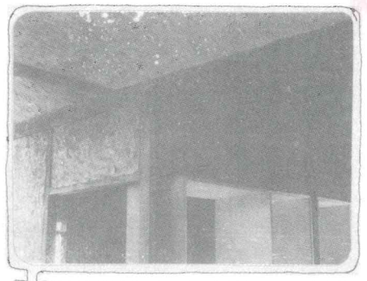
POSITIONING OF THE DOOR FRAME IN THE CURVED WALL.

ANCHORING DOOR FRAME AND CURVED BAMBOO WALL PANEL.



BAMBOO DOUBLE WALL PANEL BEING PLASTERED FROM BOTTOM.

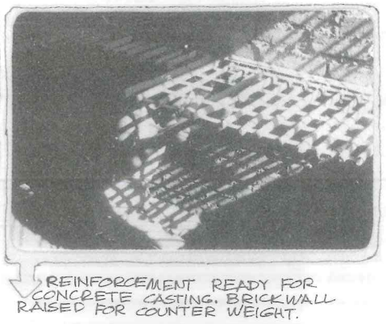
PLASTERING OF THE ROOF PANEL FROM UNDERSIDE TO FORM A CURVED CEILING.



APPEARANCE OF WALL & CEILING PANELS AFTER THE FIRST STUCCO COAT OF PLASTER.

FINISHED STRUCTURE WITH DOOR FRAME, BEFORE PLASTERING.

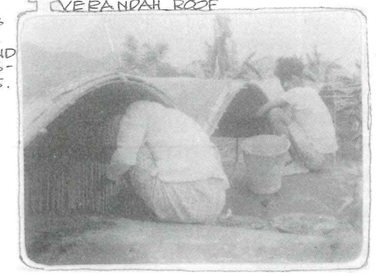
POSITIONING OF BAMBOO REINFORCEMENT FOR A BASIN COUNTER FROM THE TOILET WALL



REINFORCEMENT READY FOR CONCRETE CASTING. BRICKWALL RAISED FOR COUNTER WEIGHT.

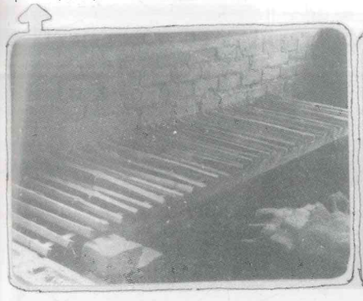
CURING OF THE CEILING AND WALL PLASTER COATS.

FINISHING OF EXTERNAL WALL PANEL IN THE SPACE BETWEEN MAIN-ROOF AND THE LOWERED VERANDAH ROOF



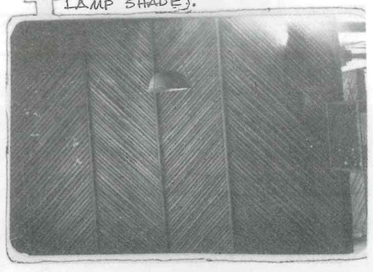
FIXING OF RAIN-WATER SPOUT

BAMBOO REINFORCEMENT TAKEN OUT FROM KITCHEN WALL FOR COOKING PLATFORM CASTING

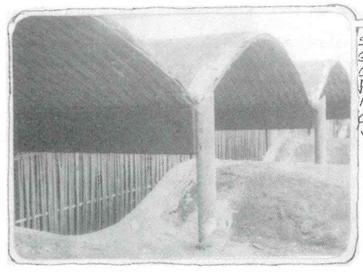


PREPARATION OF REINFORCEMENT FOR A PRE-CAST SEPTIC TANK COVER.

DECORATIVE BAMBOO PARTITION IN TIMBER FRAME. (AN EARTHEN BOWL HUNG WITH CHAIN AS A LAMP SHADE).

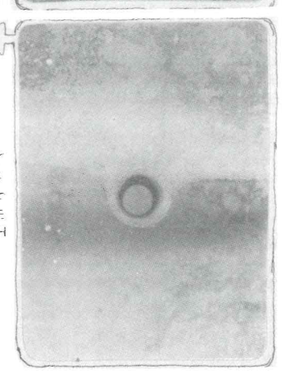


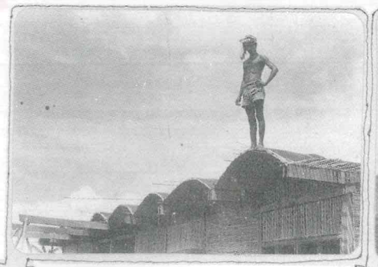
A 2" ϕ ASBESTOS PIPE PIECE BEING USED AS THE RAIN-WATER SPOUT WITH A SINGLE G.I. SCREW.



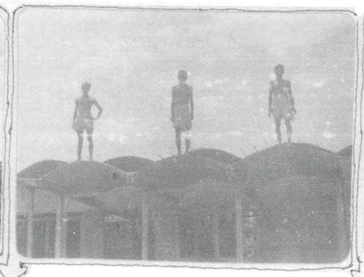
RAIN-WATER SPOUTS TO GUIDE FALL OF WATER FROM THE MAIN ROOF ON TO THE VERANDAH ROOF.

RAIN WATER SPOUT AS SEEN FROM ABOVE. FIXED IN THE ROOF VALLEYS.

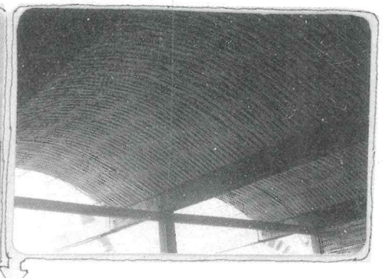




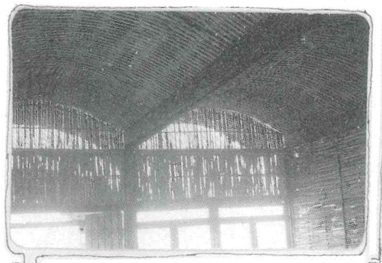
RIGIDITY GAINED AFTER CEMENT MORTAR TOPPING ON BAMBOO PANELS.



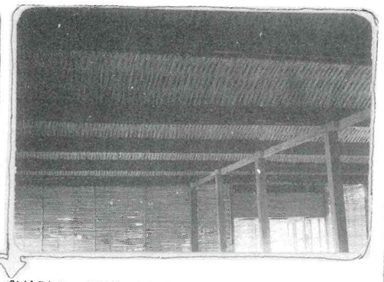
THE RIGID PANELS ARE STRONG ENOUGH TO TAKE GOOD AMOUNT OF LOAD.



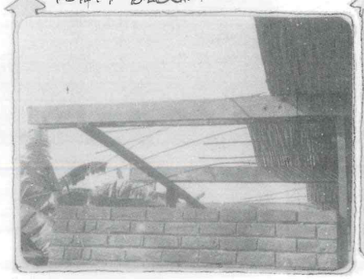
EXTENSION OF ROOF BEAM OVER TOILET BLOCK



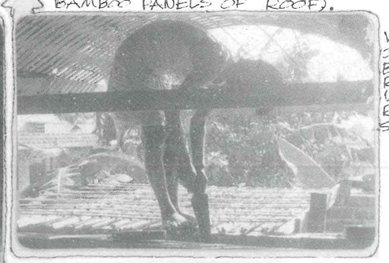
JUNCTION OF ROOF & CIRCULAR HEADED WALL PANEL. UPER PORTION SINGLE AND LOWER PORTION OVER WINDOW FRAME) DOUBLE PANELLED.



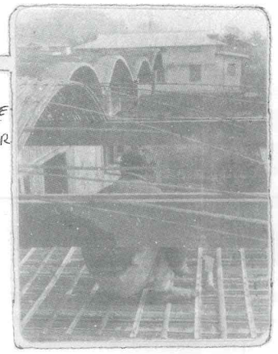
SIMPLE STRUCTURE OF POST-TIE & ROOF BEAM. CEILING AS SEEN BEFORE PLASTERING. LARGE WALL PANELS CONCEAL FRAMEWORK, AS THESE ARE DOUBLE PANELLED HOLLOW WALLS.



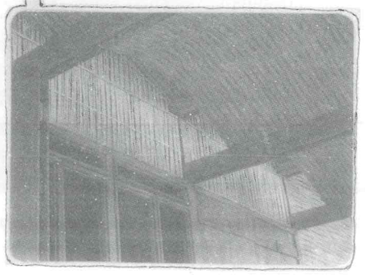
EXTENSION OF ROOF BEAM FROM POST TO BRICKWALL OF THE TOILET BLOCK



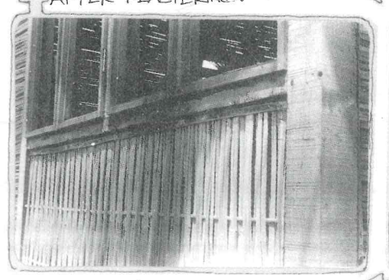
PREPARATION FOR THE BAMBOO REINFORCED SLAB FOR BUILT IN WATER RESERVOIR AT LINTEL HEIGHT OVER BRICKWALL OF TOILET BLOCK (UNDER EXTENDED BAMBOO PANELS OF ROOF).



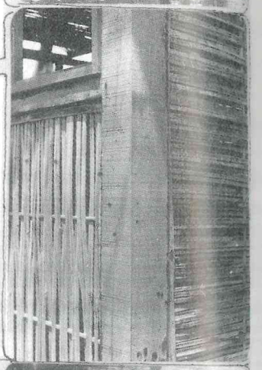
WORK ON THE BAMBOO REINFORCEMENT OF RESERVOIR SLAB.



CONNECTION OF BEAM & POST OF LOWERED VERANDAH ROOF. ROOF PANEL KEPT AWAY FROM WALL TO FACILITATE LIGHT & VENT.

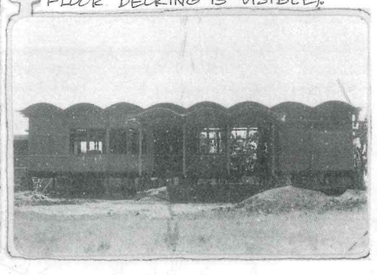


JUNCTION OF TIMBER FRAME & WALL PANELS. WALL FLUSHES ON BOTH FACES OF TIMBER FRAMEWORK AFTER PLASTERING.

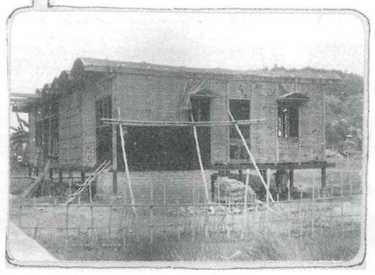


CEMENT MORTAR TOPPING ON ROOF PANEL, EXTENDED OVER TOILET BLOCK, SUPPORTED ON BRICK WALL. WATER RESERVOIR IS FORMED BY BK. WALL OVER SLAB AS SHOWN.

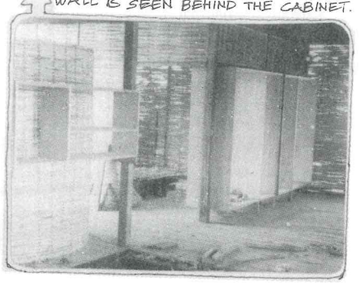
COMPLETED ROOF HOUSING THE RESERVOIR



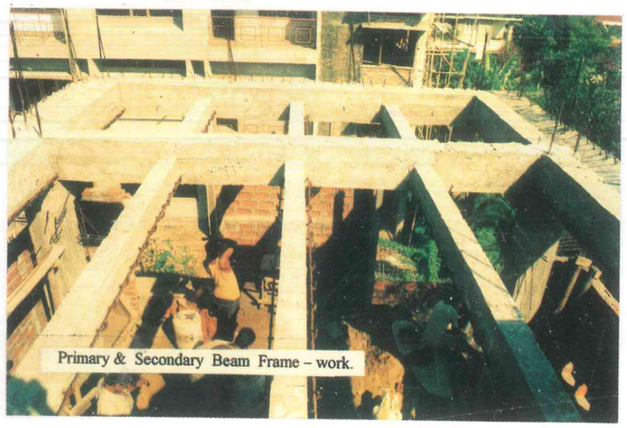
AFTER THE ROOF TOPPING IS COMPLETED AND ALL THE BAMBOO WALL PANELS ARE DONE. (TIMBER FLOOR DECKING IS VISIBLE).



BRICK PLINTHWORK OF KITCHEN AREA AMALGUMATED INTO TIMBER FRAMEWORK.



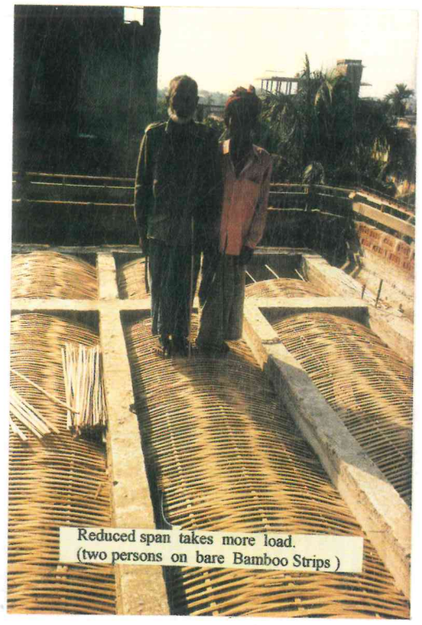
BAMBOO WALL PANELS AND THE IN-BUILT CABINETS. FREE STANDING CIRCULAR & FRAME LESS BAMBOO WALL IS SEEN BEHIND THE CABINET.



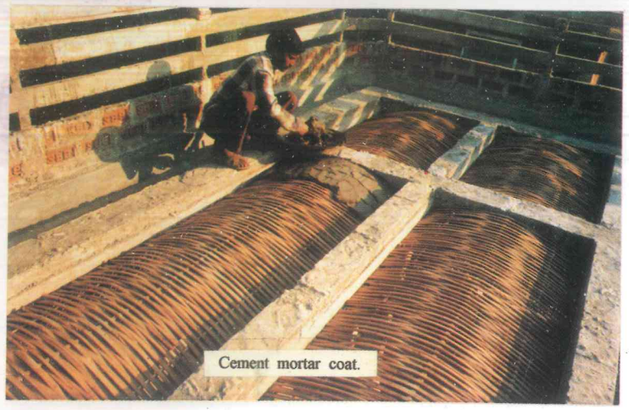
Primary & Secondary Beam Frame – work.

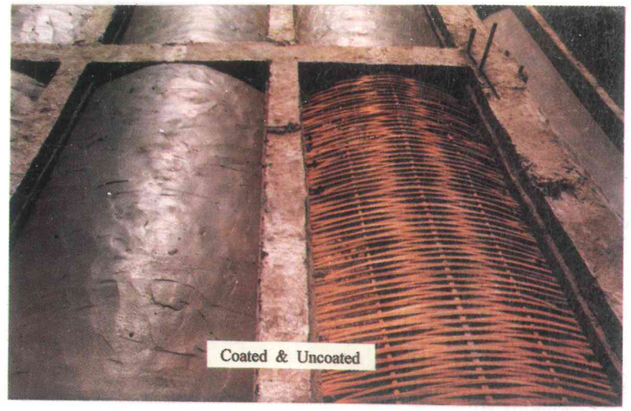
Provision for holding Bamboo Panels in frame-work
(seen from below)

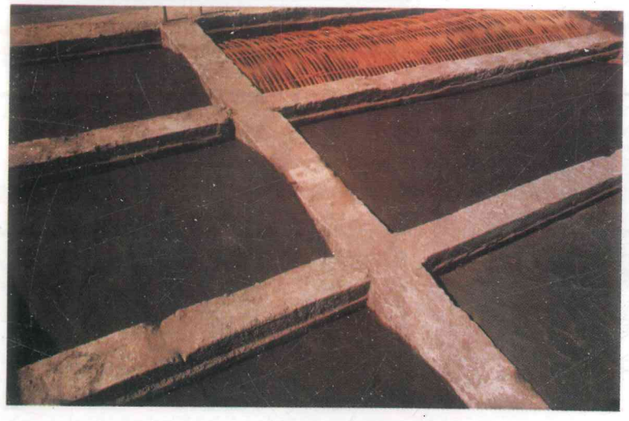
Wooven Bamboo Strips Technique reused.



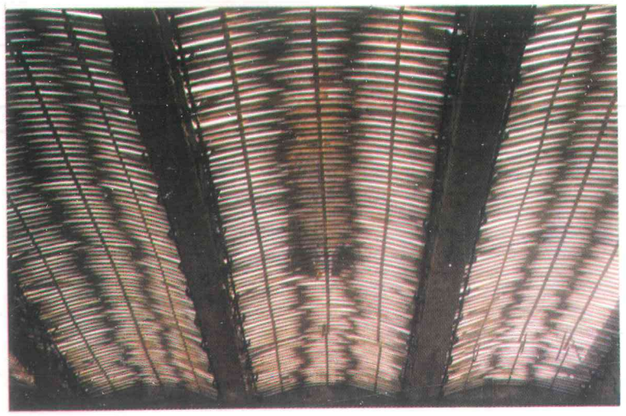
Reduced span takes more load.
(two persons on bare Bamboo Strips)

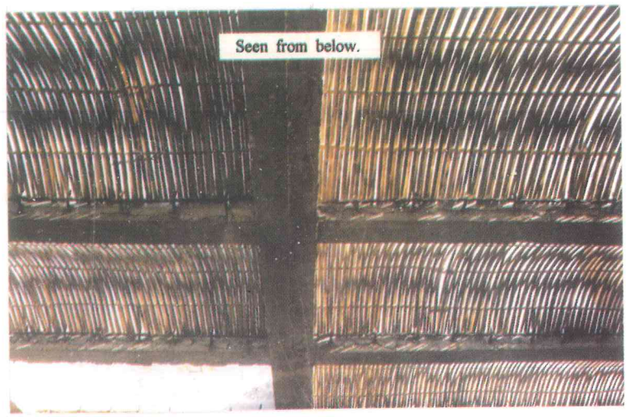

Cement mortar coat.

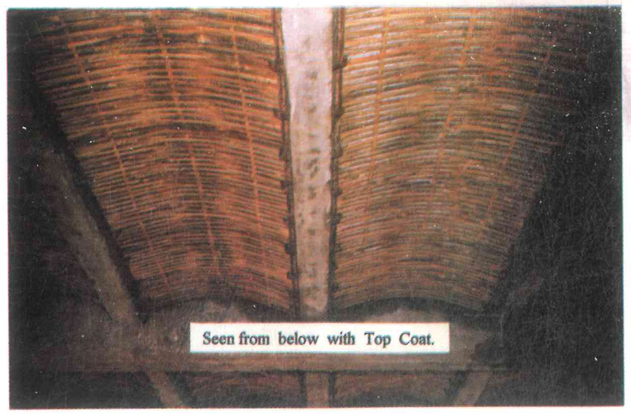

Coated & Uncoated

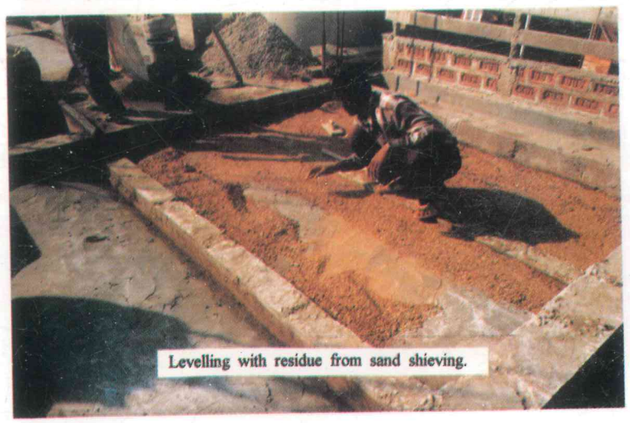



Coated and Stronger.




Seen from below.


Seen from below with Top Coat.


Levelling with residue from sand shieving.

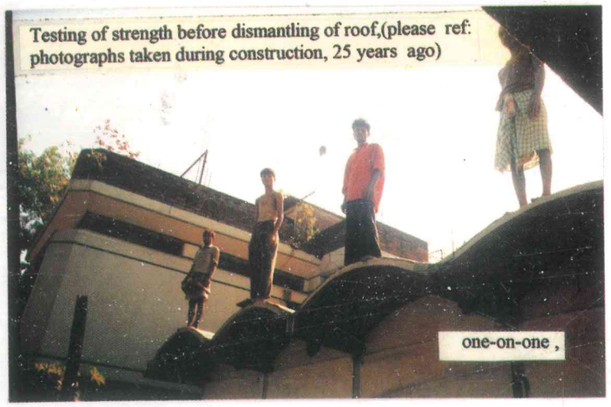

Levelling Coat of Mortar.

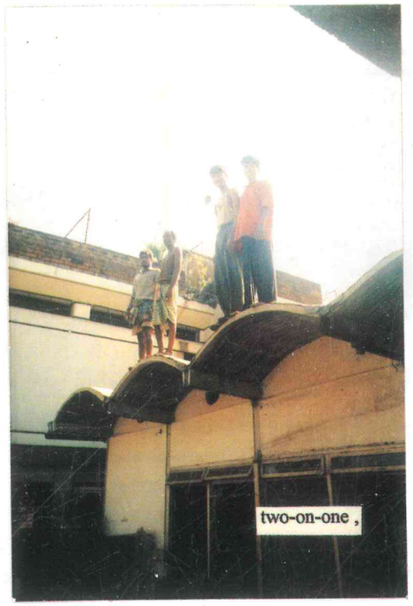

The levelled roof ready to take a Roof Garden

AN EXPERIMENTAL HOUSE : DISMANTLING

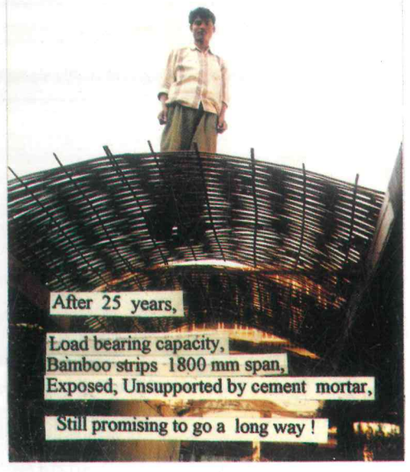
Though it cannot be said that an urban house with a single storey structure is improper landuse yet, in our case it was the demand of urban landuse that called for dismantling of the bamboo based experimental house to accomodate a four storeyed structure for the growing family need. This house, otherwise, did not call for the dismantling as the structure was in good condition and promised to last for more years. This will be supported by the photographs in the following plate taken during the operation of dismantling.

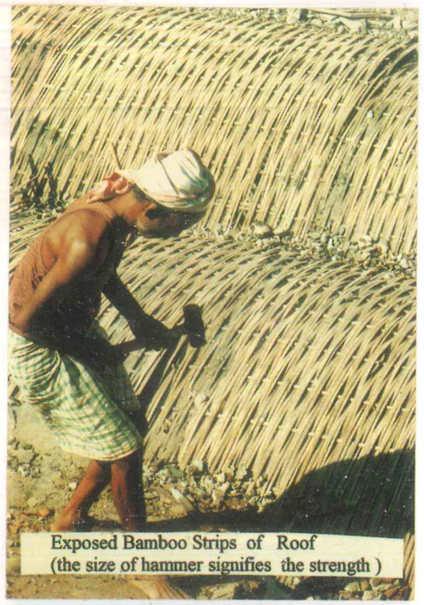
The most significant observation is the condition of the bamboo strips that were in use for 25 years inside the structure. It was a foregone conclusion that the bamboo would be lasting for a long time as this was a time tested observation prior to taking up of the bamboo based structure. Thus this has been proved that bamboo promises a very long lasting period provided that the conditions are conducive. The bamboo strips recovered from the structure have been preserved since 1998 with the hope that someday a need would be there to study the internal conditions, of long used bamboo, and its strength properties. This will add to the technical informations on bamboo. It is hoped now that the time is ripe.


Testing of strength before dismantling of roof,(please ref: photographs taken during construction, 25 years ago)
one-on-one ,

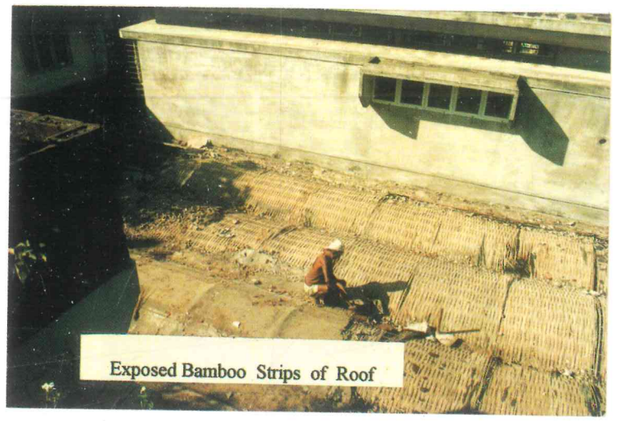

two-on-one ,


four-on-one, strong as ever !

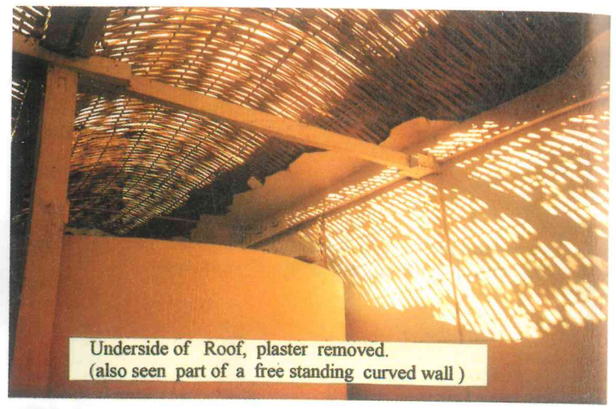

After 25 years,
Load bearing capacity,
Bamboo strips 1800 mm span,
Exposed, Unsupported by cement mortar,
Still promising to go a long way !



Exposed Bamboo Strips of Roof
(the size of hammer signifies the strength)

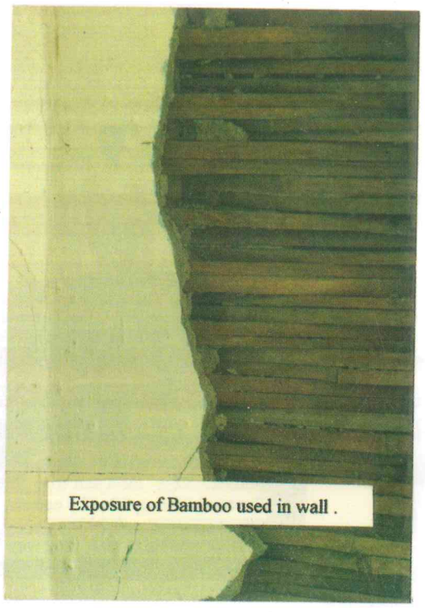


Exposed Bamboo Strips of Roof

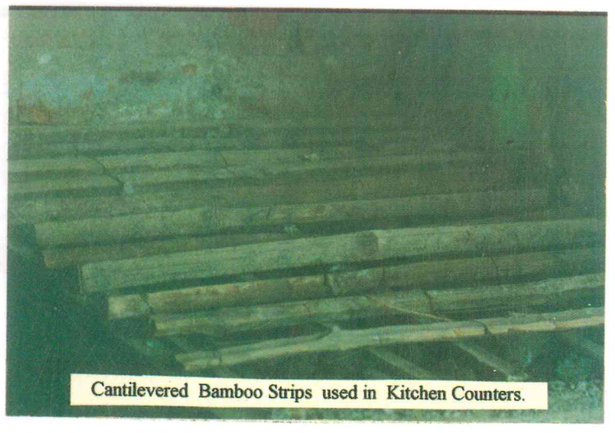


Underside of Roof, plaster removed.
(also seen part of a free standing curved wall)

Part exposure of Bamboo in curved wall .



Exposure of Bamboo used in wall .



Cantilevered Bamboo Strips used in Kitchen Counters.

Technique Re-used : New project

As a recognition to the promises made by bamboo at the end of dismantling the first experimental house, already described, the technique has been re-used in an R.C.C. framework, again for self occupation. This time, it is not only a roof but also a floor. The span has been reduced to 1000 mm, from the earlier roof unit of 1800 mm, to act as a floor also to take more load.The following photographs were taken during construction which is now complete and under self occupation. The technique is underway to try larger spans with multiple layers of woven bamboo strips and mortar stiffening with various mix of cement-sand ratio.

It is expected that, since the bamboo strips are in most conducive condition as derived from the traditional use, the lasting period will be the longest possible for bamboo that is more than 100 years.

APPEARANCE OF THE HOUSE AFTER ROOF TOPPING. EXTERNAL WALLS ARE SEEN IN ALL BAMBOO WORKS PRIOR TO PLASTERING.

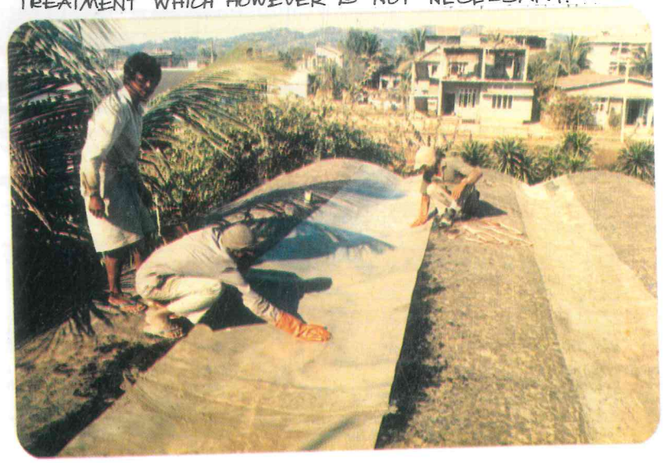
APPEARANCE OF THE HOUSE AFTER EXTERNAL WALL FINISH. DRY STONE WORK USED TO RETAIN EARTH IN THE FRONT RAISED TERRACE. COMPOUND/FOREGROUND SEEN BEFORE DEV.

APPEARANCE OF LIFE; CONVENTIONAL UNDER AN UNCONVENTIONAL ROOF.

FEELING OF SPACE IN THE FRONT VERANDAH, A GATHERING. (VIEW FROM FRONT RAISED TERRACE)

ENVIRONMENT INSIDE; A BAMBOO PARTITION, A WOODEN FLOOR A CANE PEDESTAL LAMP, A COMPOSITE CHAIR ROCKING UNDER AN UNCONVENTIONAL ROOF.

EXPERIMENTAL RE-WATERPROOFING TREATMENT AFTER 12 YEARS OF CONSTRUCTION. ROLL OF ASBESTOS SHEET IN GREEN STATE FROM FACTORY BROUGHT AND LAID ON ROOF AND ALLOWED TO SET & CURED. THE SHEETS FOLLOW CONTOUR OF CREST & TROUGH OF THE ROOF. THIS WAS TAKEN UP ONLY FOR THE REASON THAT THE FACTORY OWNER IS KNOWN AND WHO OPTED FOR THE TREATMENT WHICH HOWEVER IS NOT NECESSARY.



LARGE PLAIN AREA OF DOUBLE PANELLED HOLLOW BAMBOO & CEMENT PLASTERED WALL. WOODEN FRAME IS CONCEALED BETWEEN BAMBOO PANELS. (DOUBLE SKINNED WALL CONSTRUCTION.)

WOODEN FRAMED, LARGE & LIGHT DECORATIVE EXPOSED BAMBOO PARTITION. WOODEN BAMBOO MAT SANDWICHED BETWEEN TWO HALVES OF BAMBOO. FINISHED IN POLISH.

JUNCTION OF LARGE PLAIN WALL, DECORATIVE BAMBOO WALL (ANOTHER TYPE) AND A WOODEN FLOOR.

"POOR MAN'S TIMBER" COMES TO URBAN AREA
CAN WE GRADUALLY REMOVE THE STIGMA?

EXPOSED BAMBOO : DELICATE & BEAUTIFUL.
CEMENT & CONCEALED BAMBOO : STRONG & BEAUTIFUL.

CONVENTIONAL FURNISHING IS NO PROBLEM.

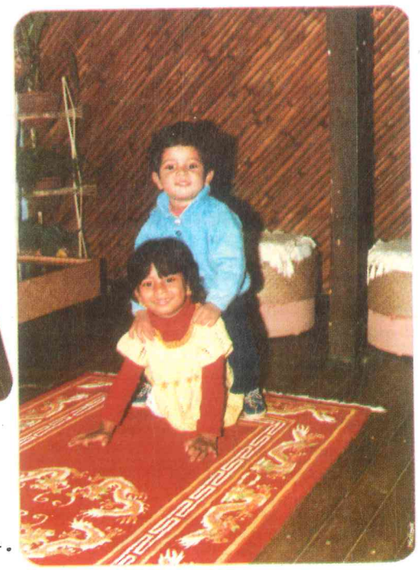
THE STRUCTURE ACCOMMODATES WELL.

PLAIN PLASTERED CEILING
PLAIN PLASTERED WALL
WOODEN ROOF BEAM.
CLUSTER OF EARTHEN BOWLS AS LAMP SHADE (3 BOWLS)
SMALL VENTILATOR WITHIN WINDOW FRAME

A 6'×12' PLANNING GRID PROVIDES FOR LARGE HALL TO HOUSE A GOOD GATHERING (12'×18' HERE)

A 8' ϕ CIRCULAR WALL IS A ROOM WITH A PARTITION IN BETWEEN A CHANGING SPACE AND A PRAYER SPACE (SEEN AT DISTANT END *)

A TILT FROM THE CONVENTION,
BUT STILL A HOMELY HOME.



PART - II

WORDS PREFATORY :

The recent contact with CBTC and tremendous encouragement received from it has revived my interest in the field of Bamboo construction again. This has called for **updating myself** on the knowledge about present day activities elsewhere on bamboo, as I have been cut off from the same since my last studies done about 30 years ago, to join hands with others in the same field today and to share views and ideas for the cause of bamboo.

In the process, I have gone through few books that were made immediately available to me by CBTC and have formed some **ideas to share**. The process has been a quick one as we are to share our views starting from the platform to be offered by the 1st international workshop in the North East India on bamboo construction (Oct. 29 – Nov.12)

Bipul Kumar Das
October 10, 2001.

Updating Myself :

Here I have put myself as an example of a person who is interested in updating himself on the informations avoilable on bamboo as a constructional material today.

Thus, my search has been to gather books, documents, discussion papers etc. containing information on bamboo as a basic structural material. And in the process I have come to know about INBAR. Assuming that INBAR being an international organisation has the best and global information and the publications cover almost all the up-to-date and concise informations on bamboo as sought for. I have gone through few such publications. I have also gone through few other non-INBAR publications as well.

Here, I shall not refer to any particular books or-authors or – scientists or – designers, though I fully endorse the tremendous underlying efforts of theirs, as the message that I am trying to convey is different. It is about the kind of general picture about bamboo one will frame after going through the informations available.

The picture thus framed reflects as follows :

On the material, there are considerable amount of informations on the botanical aspect of bamboo including its cultivation etc. where the work is going on with a direction. While there are informations available on mechanical and structural strength properties in respect of freshly cut green as well as dry and seasoned bamboo there seems to be no such informations on the old and used bamboo which are found in good condition. There are bamboo available which have already lasted for very very long period.

We can say here that there are no comprehensive database available for ready reference as has been said in a book itself wherein a model table has been provided with incomplete date to have an idea only. Here the diameter of bamboos and their relationship with wall thickness are not clear. The variations shown in the diameter of a particular specie probably is related to the variations of the height of that variety. For example – if height is recorded as 15-18m, diameter as 60-100 and walk thickness as 25-30, it probably will mean as height 15m, diameter 60 mm and wall thickness 25 mm. Wall thick- nesses indicated as *'thin', 'thick', 'thickish' or 'moderate'* give vague idea. Similarly internode length said as *'long'* and *'short'* are not clear information. However, the table probably indicates that within a particular specie there is a range of bamboo with varied dimensions under different names and in different locations. But the fact remains that we do not get a clear picture.

On durability of bamboo, a book informs that the life of untreated bamboo cannot be more than 5 years in page no 1 while in page no.3. it says that it can be as high as 10-15 years. Another book in page no.6, it says that bamboo falls in non-durable category, but in page no.7, it says that a bamboo house with ceiling and walls plastered with cement mortar has lasted more than 90 years. Yet another book says that even if bamboo is regarded as a second class material by some, there are houses where bamboo has been used extensively and are 50-100 years old. (When it is fact that myself have witnessed 60 years old untreated bamboo strip in mudplastered wall, 40 years old whole bamboos being reused in a house, 60 years old roof structure and my own experimented house after dismentling has shown untreated bamboo strips in tact after 25 years, the kind of informations that bamboo is a temporary material and does not last long sends wrong signal to the reader).

On preservative treatment, one can gather that methods of treatment are quite satisfactory in case of chemical treatment and we know how the chemical will resist decay in different conditions. Regarding the method of smoking there is room for a reader to expect some kind of definite explanation of the internal changes in bamboo after smoking that help fight decay.

In the field of construction, the joineries are the basic requirement in the system like grammar in a language. While the joints using split or shaped bamboo (Like in small trusses) seem to be simpler and confident, the whole bamboo joineries (except in cases like filed ones) seem to be the work of skilled craftsmen and with less confidence. Every joint seems to need perfect fitting for it's efficiency and truly speaking no two bamboos are exactly same (unlike manufactured metal tubes) and thus perfection is compromised. In fact it appears as if the whole system of construction of building is huge scaled handicraft. This system of whole bamboo joineries may not be practical for standardisation and mass production of houses but may be suitable for do-it-yourself kind of schemes where again efficiency of the structures will vary in terms of strength. In this

context the following points may be noted. – In one of the books expression is _.... *the upper end (from diagonal in the truss) should fit* ***precisely*** *around the form of the horizontal lower member. This requires* ***good craft skills*** ..... ***deformation*** *can be considerable for the joint even if the lashing is tight, it might be that the joint resists only shear force after some* ***displacement*** ... In another it is written as _.... *Because it is hollow, jointing of two or more members is a problem. ..... Bamboo has a tendency to split easily ..... cannot be nailed without preboring. In one earthquake resistence test project it is said .... collapse occured mainly because of yielding of the joints. Yet another book says ..... In fact joint play an extremely significant role in the behaviour of bamboo structures and this is another field where very little data is available.* Thus, reflection from the picture one gets is that perfection has not been attained in the system of bamboo joineries.

Regarding reinforcements and bond with concrete one gets a vague picture which does not show clearly whether or not bamboo as reinforcement in concrete is successful. In one technical report it has been said at the end of an experiment .... *long-term, in-service observations and testing for bond integrity will be necessary before definite conclusions can be drawn* ... There are suggestions of bamboo to be coated with varnish for improving bond but there are no indication about how permanent is a coat of varnish. About bamboo cable reinforcement a paper says ... *by making 'cables' by twisting or braiding strands from the outer portion of the culm, and utilizing the same for reinforcement, stable bonding is possible. Thus, bamboo can successfully be used as reinforcement in concrete.* But in the conclusion drawn from an experiment the paper says ... *the tests proved bamboo cables to be the most efficient (among the group*s). This appears to be a comparative statement and not an absolute conclusion to the reader. Moreover, looking at the profile of the cable one feels that there is room for assuming that concrete will not be in full contact with surface area of the bamboo cable as there are enclosed voids created by the twisting cable and as such it may pause as difficult area for engineering calculation.

On engineering and design aspect a reader understands that very little headway has been made because the behaviour of whole bamboo poses as a hard nut to crack for the designer on calculations. A book says ... *Determination of the critical load on bamboo culms is difficult because of the variation along the culm axis of the MOE, thickness and diameter, and by the presence of nodes and the variations of the said factors in the nodal region. Lastly, the inherent crookedness of the culm induces early P-delta effect .... Hence there is need for establishing a method to gather the most important parameters for every species, every batch, plantation period. area and country, so that the results obtained can be included in a code of practice.* Another book says – ... *timber a traditional material, became the subject of comprehensive, scientific and technological studies and gained a well-deserved place among modern engineering materials. Bamboo though a traditional construction material for thousands of years, has still to gain equivalent status.* The book also says that process is on to find out proper engineering recommendations for the structural design of bamboo elements, components and joints. The book further says ... *although the physical and mechanical properties of Guadua have been studied and methods have been proposed and some of their joints, it is not possible to produce reliable models for structural analysis of traditional construction* ... therefore the picture on the aspect of whole bamboo structural design reflects that the breakthrough is yet to come which is in process.

On the standardisation and international building code front reader will come across expressions like ... *Are we willing and able to do this ? ... In the opinion of the author this is a interminable discussion between scientists and engineers. The scientist among us are right : We do not know enough about bamboo to design such an international model of standards.* But the fact remains that the process is on and the view is optimistic. It has been said ... *the INBAR has been working along these lines .... and there are reasons for optimism in the near future (1996).*

It may be concluded by saying that the updating is – much has been done, – much are in process and – much more are yet to be done for the cause of BAMBOO.

IDEAS TO SHARE :

It is obvious that single handed and in isolation is no way to work for a cause like utilising the versatility of bamboo in the field of construction. It has to be a well concerted move of mass participation towards a goal as a team. The team where architects, engineers botanists, horticulturists, chemists, laboratory technicians, field workers and the like will be involved in the visualisation and R + D part of it while politicians bureaucrats, financial institutions, builders and the like will be associated with the policy making and implementation part of it. But, for all to co-ordinate through will be an apex body role which must be played by INBAR to-day. Anybody who wants to know anything about bamboo, technical or non-technical, for R + D work or for gathering knowledge for policy making or for anything else must have to look up to INBAR to receive authentic and undisputable informations. If we think global, INBAR must come upto such a level of recognition that anything technical or non-technical bearing the seal of INBAR will be easier for any standardising authority including ISO to recognise and thus certify for mass acceptance. Responsiblity of INBAR shouldnot be limited to only networking but also to monitor that only the true and meaningful messages about bamboo are conveyed to the mass poople. This is a very very important task for the cause of bamboo. This calls for a central database and information screening cell associated with INBAR. It may be helpful and a practical way of screening by adopting a method similar to opening a folder of screened information on each head of information and then go on loading with files of newly screened informations that keep flowing in from R + D work from all over the world for up-to-date and ready information to share.

To touch upon few other points to share view with may be – lasting period, reinforcement and bond with concrete, joineries of whole bamboos, standard database, engineering calculations, international standardisation and code of practice of engineering use.

Like we should discourage and try to remove the stigma 'bamboo is poorman's timber' as unreasonable for bringing the right status to bamboo that it deserves, we should also stop forthwith terming bamboo as non-durable material which is untrue for the fact that bamboo lasts over 100 years if the use is not a misuse for which the user is only responsible. Both cannot be true that it is a nondurable material but also lasts for 100 years.

Regarding bamboo as reinforcement in concrete it may be prudent to accept that there has to be some change in the direction of our approach to the problem as the process has been going on for atleast over 30 years inspite of poor bond of bamboo with concrete – one is organic with much shrinkage and the other is alkaline material with unmatched shrinkage. Probably we will have to try bamboo as reinforcement but without direct contact with concrete and still be with it. That is use of pretensioned bamboo strips with mechanical end grip with concrete.

Most of the joineries of whole bamboos are examples of compromise on actual strength of bamboo. They are basically craftsmanship oriented. The underlying phenomenon of whole bamboo house may be compared with that of a timber log house to understand better. No two members are exactly similar in nature, joints are individual skill oriented, engineering calculations will not hold good as shapes and sizes of the elements are varying. There cannot be standardisation of timber log houses. Code of practice for timber engineering cannot be referred to. That means the basic material (timber) has not been shaped to respond to engineering commands. A bamboo house out of whole bamboos is just a finer version of a loghouse. Now, applying the same logic to a bamboo house can we derive that a shaped bamboo structure will respond to engineering commands ? That means sized bamboo may be a solution to the engineering problem. This may also entangle other problems like engineering code of practice and an international standardisation to follow. If that be so, the real challenge will be to work out details of construction with shaped bamboos. Unlike structural timber members that are downsized from large logs, bamboo structural members are to be upsized from smaller sections of shaped bamboo. This upsizing of members, to match structural need, may be of solid type or built-up frame type. The system of construction will be guided by the development of structural members and their joineries. If we have to strike upon a standard system, or several standard systems, of construction (like simple post and beam, post and truss, loadbearing wall unit with floor/roof, 3–D spaceframe, shell structure out of wooven – bamboo and stiffened with mortar, bamboo pre-stressed concrete system etc) we must dictate terms to bamboo and not let bamboo dictate terms to us.

After having accepted the approach of using shaped bamboo only. to facilitate standardisation etc.

the question arises as to what kind of technical database will be required for reference. Since bamboo is to be shaped the first requirement is physical. That is - diameter, wall thickness and internode spacing. Since diameter has an approximate proportion to the height, the first table of reference may be silent about the same and a side reference table may be introduced for the purpose. Second is the strength properties. Here, we must remember that it will not base on a whole bamboo but on strips of bamboo with and without, nodes, size a specifications of which may be worked out to suit the purpose. If these were dependant entirely on the species and there were no variations within the specie irrespective of the diameter and wall thickness and location of growth then mention of the specie in the first table would be sufficient with another standard table of species with strength properties for reference. But since it has been found that the strength properties vary even within a specie according to location of plants, the next alternative is to classify bamboo according to location (country or regionwise) and their strength properties. The classification will be the common measuring scale which is the bond of standardisation. For example 'class I' bamboo in country 'X' is equivalent in all technical aspects to 'class I' bamboos of countries 'Y' 'Z' etc.

Therefore, a standard design of a structural element using a particular class of bamboo will hold good in any other country or place with that class of bamboo available locally there. Every country or region will have a central bamboo testing laboratory, the working methodology of which will be governed by an international standard which may be determined by INBAR so that the classification is standardised. It may be possible that a particular class of bamboo will include various species with varied diameter and wall thickness etc. to choose from. They may choose bamboo for shaping according to the purpose which it has to serve. The classification will basically be guided by the strength properties and number of classifications will depend upon the total range of strength and the theory of average, since it is a natural material, will be a major consideration (which will include factor of safety) while ascertaining the varieties to be included in a particular class or group. Here, though the specie name does not figure yet there may be a table on species with data other than strength properties to know about the general characteristics to decide on factors like preservation, appearance etc. A standard table thus may look like the one given as under (which is open for modifications).

COUNTRY : 'X'	
Class : I	s A d/t/n
with NODE	
comp : ten : Elas etc.:	s Bd/t/n s C/d/t/n
without NODE	etc.
comp : ten : Elas etc :	etc.

'X' : name of a country or region

A,B,C, : vernacular name of Bamboo
s : Specie identity code
d : Diameter of bamboo
t : Wall thickness
n : Nodal spacing

Adopting to shaped bamboo in structural use should eliminate calculation hurdles like-crookedness/wall thickness variations/tapering cross sectional area etc. of bamboo and facilitate better joinery details and standardising of design method and a code of practice to follow.

A parallel method of standardisation may be thought as a patented design of one entire system-built house where every component is testified with destructive tests and certified be a standardising authority for releasing the product into the market. Acceptance of the product will depend on the merit of such a product itself and also on the marketing skill. Sooner or later this type of pre-fab building system with bamboo probably will fill the market as a sold commodity with their own specifications and construction manual.

Ratio of maturity period to lasting period in timber on the average may be taken as 1 : 4 but that of bamboo may be taken as 1 : 20. Thus, even if we consume more bamboo in a construction system where whole bamboo are not used (consumption of bamboo per unit of dwelling wise) still the system will not be a diminishing factor in availability of bamboo as the system will outlast other conventional house where recurring and frequent replacement of bamboo are needed. If we accept bamboo as not non-durable material and use it in a way that it lasts longer are indirectly planting bamboos with every houses we make. It will be relevant to add here that as far as the traditional house are concerned, we should make it a point that only treated bamboos are encouraged to be used

(where frequency of replacement is more) and the responsibility of such a move should lie on the department who undertake cultivation of bamboo (may be the department of forestry) to provide with facility for free treatment of bamboo because a bamboo post saved today, which otherwise would be replaced in 3 years, is saving 27 posts in three years. That would be an indirect way of cultivation for the department of forestry that may be logically included in their programme.

However, utility of whole bamboo, nature's gift to mankind, will always prevail in the fields of conventional practice like scaffolds in multistoryed structures, support for concrete form work (shuttering and shoring), large pandal construction for temporary festive use, quick shelters during disaster management etc whereagain we should introduce the economics of preservation treatment. That is - cost of preservation treatment of a whole bamboo is much less (almost 1/3) than the cost of bamboo itself which will extend the life in exposed condition three folds. Here again we are indirectly planting bamboo. This will also help to enhance the image of bamboo in the eye of the mass because less we see rotten bamboos around more we accept the permanency of bamboo as a material.

It may be concluded by saying that there will be lot more stockpiling to be shared in the coming days and years.

SOME CONCEPTUAL PROPOSALS

Forming a concept to the approach of solving a problem, or planning something, is the most important and significant step towards it. Identifying the problem in its right perspective is like almost going half way through towards the solution. That means if we are in the right track, we are sure to reach the target. But there are some venture where the track never seems to be ending which keeps on opening new vistas and is a continuous process. Venture into the versatile field of bamboo construction is one such example. It will go on and on at changing pace, some time faster and sometime slower, but we must not get derailed. To be on the track, we need support of the instrument called logic. Logic is more powerful when it is screened by many minds. There is where we need the team work and the network.

The following pages include some proposals which are in different stages of processing. Most of them are in the conceptual stages calling for details and may be improvement or modifications too. And this will depend on for how long the C.B.T.C. will be supporting such R + D work in the Northeast India as it has a limited time frame.

The effort made under a short notice, in parallel with my professional architectural practice, hopefully should carry atleast some message, however insignificant that may be to start the process of interaction for a concerted effort much bigger.

PROPOSAL FOR AN
EXPERIMENTAL DEMONSTRATION :

In a single demonstration the efficiency of (1) Bamboo-to-metal grip joint (2) Bamboo-to-bamboo grip joint and (3) Bamboo-to-concrete grip joint may be ascertained.

The weight of the concrete block at bottom shall be equivalent to tensile force resisted by bamboo at 'a'. This may be equivalent to maximum workable tensile strength of bamboo.

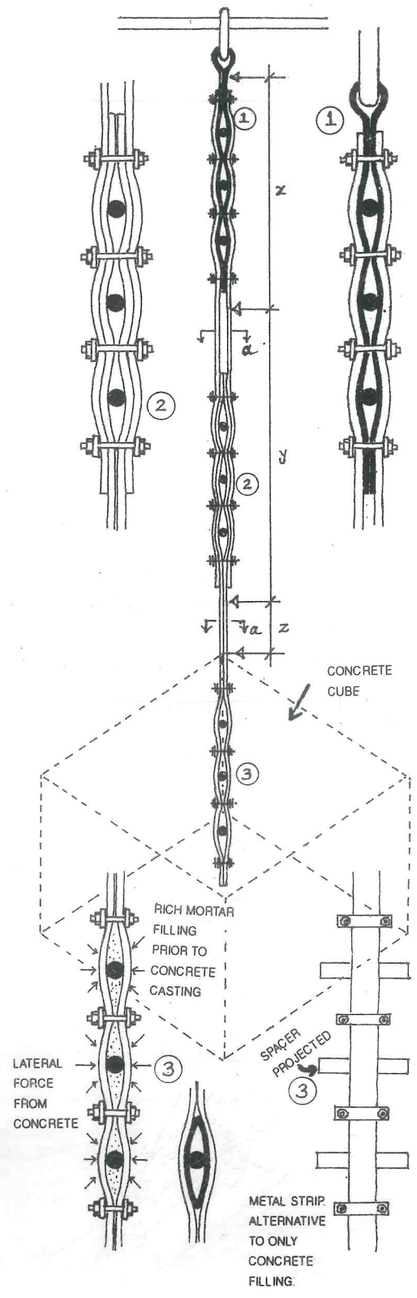
The metal strip used for joint 91) shall be specified to resist more than applied load of concrete block.

If there is failure in joint (1) then 'x' lenth will increase. similarly for joint (2) 'y' will increase and for joint (3) 'z' will increase.

If there are no changes in joints after removing support to concrete block from bottom, then efficiency for working tensile strenth of joints are proved as 100%

Depending on the result, number of grips may be increased or decreased.

There can be more load applied over the concrete block until the bamboo strip snaps. And if till such time the joints do not fail, then efficiency of joints will be more than 100% such a joint is preferable for engineering calculations.



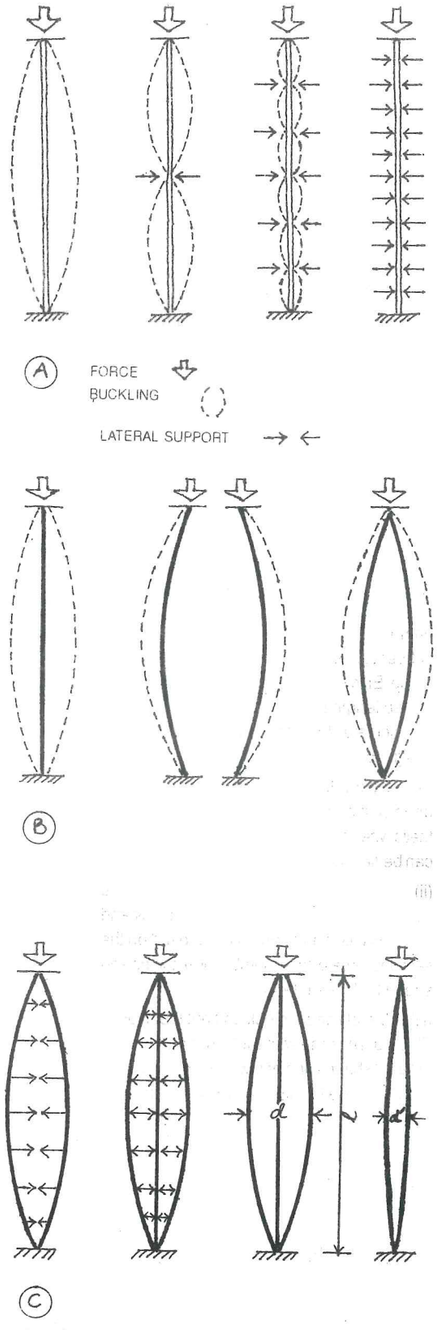
PROPOSAL FOR A COMPRESSION
BUILT-UP MEMBER FROM BAMBOO STRIP

Due to elastic quality, though the compressive strength of bamboo along grain is very high, bamboo as a structural member in compression will fail due to buckling much before the inherent compressive strength is fully attained. That is, bamboo in compression will normally fail in buckling much before crushing. Therefore, success in designing a compressive built-upmember will rest on its preventing from buckling.

A bamboo strip will bend or buckle either way in the direction of its smaller depth. Therefore, suitable lateral support, in this direction will allow a bamboo strip, to carry more compressive stress, without buckling (Ref A). The cross sectional area of bamboo strip in compression may be calculated accordingly to the force it has to resist and if this section is laterally supported suitably, the Goal will be attained. How much lateral support will depend on the cross sectional area of member under compression.

As already said a member under axial compression may tend to bend either way (in the direction of smaller depth) but a bent member will bend further in the same direction (Ref B).

Now, if two members bent in opposite direction laterally are tied together and pressure is exerted axially then they will support each other from bending further provided that the cross sectional areas and length of the member are similar.



PROPOSAL FOR A TENSILE JOINT OF BAMBOO STRIPS.

Since Bamboo is very weak in shear along the grain, jointing by bolt or nail or screw shall not be suitable to use the full tensile strength of bamboo.

Therefore, a joint like 'A very tight grip' using full cross sectional area should be most suitable. A very tight grip joint will depend on the ability to develop high frictional resistance at the joint to resist force applied to the joint.

Referring to the sketches along side –

(I) 'O'FRICTION

(II) 'LITTLE'FRICTION DUE TO SUFRACE CONTACT.

(III) 'MORE FRICTION' DUE TO APPLICATION OF FORCE AT RIGHT ANGLE TO SURFACES IN CONTACT.

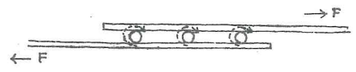
(IV) 'MAXIMUM FRICTION' DUE TO DEFORMED SURFACES AND APPLIED FORCE.

Using the inherent & unique quality of bamboo this joint can be perfected by using different shapes/sizes/material at the spacer & grip. Efficiency of the joint is proportional to the lap length i.e. number of grips which can be calculated by field testing. The grip can be designed –

(i) Synthetic spacer & Tie : This can be done with synthetic spacer blocks and synthetic wire tie amulgammated with glue. Which can be field tested.

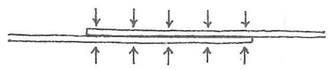
(ii) Bamboo spacer & Tie : This can be done with vertical grain bamboo spacer block and metal wire tie and strength will depend on the sectional area of wire, number of windings and strength of the material.

(iii) Metal spacer block and nut & bolt grip : This can be done with metal spacer block of different shapes and grip with nut & bolt. Which can be done with standard design method.

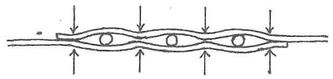


NO FRICTION

II. LITTLE FRICTION

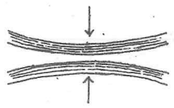


III. MORE FRICTION

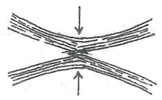


IV. MAXIMUM FRICTION

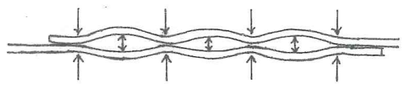
CONSIDERATIONS :



MILD CURVATURE AT GRIP, FIBER UNDAMAGED

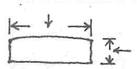


SHARP CURVATURE AT GRIP, FIBRE DAMAGED



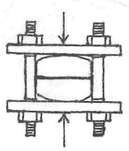
SURFACE CONTACT AT GRIPS IS ESSENTIAL FOR STABILITY & FRICTION DEVELOPMENT

MORE SHRINKAGE DUE TO LARGER DEPTH



SHRINKAGE

MINIMAL SHRINKAGE DUE TO SMALL DEPTH, NO EFFECT OF SHRINKAGE ON GRIP.



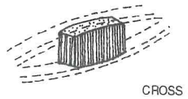
A STEEL NUT & BOLT GRIP IS PREFERABLE TO PRE COMPRESS BAMBOO STRIP TO AVOID EFFECT OF SHRINKAGE ON GRIP.

The joint promises perfection to such extent that the material shall not fail at the joint. Thus promising fullest use of strength of Bamboo in tension.

DEPENDING ON THE PURPOSE OF THE JOINT THE SPACERS AND AGIP MAY BE SELECTED.

SYNTHETIC SPACER & SYNTHETIC GRIP

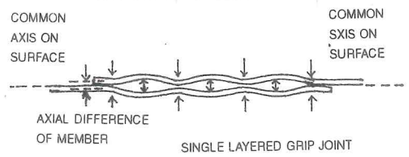
BAMBOO SPACER & WIRE GRIP



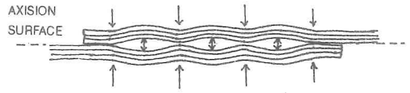
CROSS GRAIN BAMBOO SPACER

METAL SPACER & NUT & BOLT GRIP.

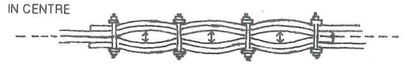
DIFFERENT TYPES POSSIBLE



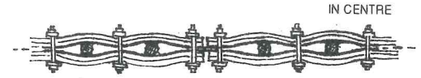
SINGLE LAYERED GRIP JOINT



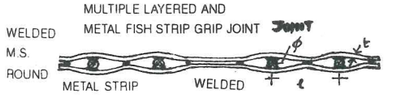
MULTI LAYERED GRIP JOINT

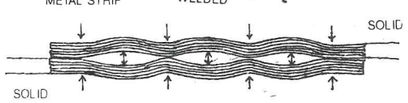


DOUBLE LAYERED GRIP JOINT



MULTIPLE LAYERED AND METAL FISH STRIP GRIP JOINT



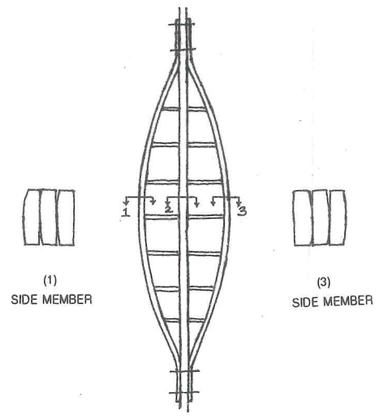


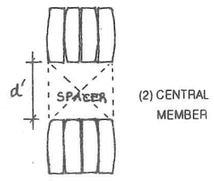
MULTI-SPLIT & GLUED : FOR THICKER BAMBOO STRIP

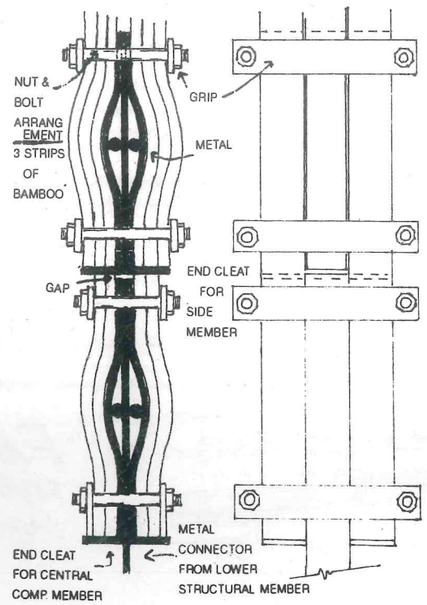
IF A THIRD MEMBER IS INTRODUCED AT THE AXIS OF THESE TWO BENT MEMBER THEN IT WILL GET EQUAL PULL LATERALY IN OPPOSITE DIRECTION. THIS CENTRAL MEMBER MAY BE DESIGNED TO CARRY THE COMPRESSION STRESS WHICH IS SUITABLY SUPPORTED LATERALLY THE SLENDERNESS RATIO OF THE WHOLE COMPOSITE . MEMBER MAY BE CONTROLLED BY 'd' & 'p' (REF. (C) FOR PREVENTING BENDING, IF ANY IN THE DIRECTION PERPENDICULAR TO THE PLANE OF THE BUILT-UP MEMBER, A 'd' DEPTH CAN BE CREATED BY INTRODUCING A SPACER OF REQUIRED SIZE. THUS A MATHEMATICAL FORMULA IS TO BE WORKED OUT TO ASCERTAIN THE CROSS SECTIONAL AREA OF THE COMPOSITE MEMBER.

THE JOINERY CAN BE METAL GRIP JOINT AS SHOWN IN DIAGRAM WITH EXTRA END BEARING CLEATS SINCE THE MEMBER IS TO BE A COMPRESSIVE ONE. BAMBOO WITH THICKER WALL VARIETY AND WITH LARGER DIAMETER SHOULD BE SUITABLE TO TAKE OUT THICK & WIDE BAMBOO STRIPS.

DETAILS OF COMPOSITE
COMP MEMBER USING GRIP JOINT.





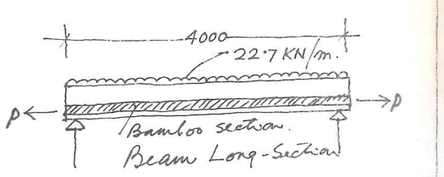


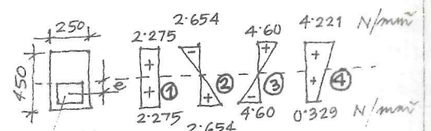
Proposal for a Concrete Beam **Prestressed** with Bamboo Strips :

Provided that the bamboo-steel grip joint is more than 100% efficient, a concrete beam pre-stressed with bamboo strips may be possible.

As a case study, based on the following data, the required area of bamboo strips in tension has been worked out as – 17062 sq.mm.

(Slab size : 4000 × 4000
effective span : 3700
grade of concrete : M-15
Beam size considered 450×250
Permissible tensile stress : 15 N/mm²
Live load = 2 KN/m² × 4 m = 8 KN/m.
Dead load = 24 KN/m³ × 0·10 × 4 = 9·6 KN/m.
Floor finish = ·60 × 4 = 2·40 Kn/m.
Self wt. of beam = ·45 × ·25 × 24 = 2·7 KN/m.

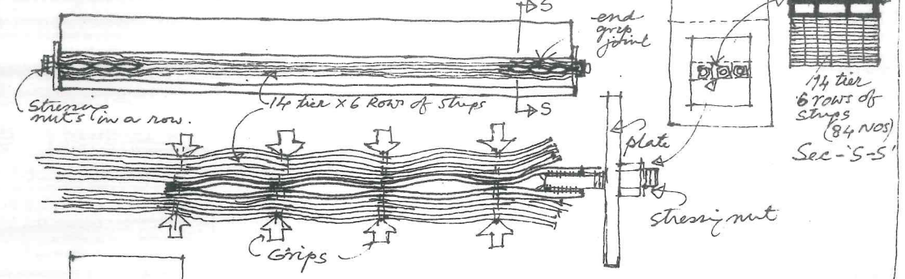


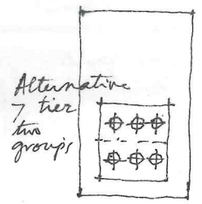


① Direct stress due to pre-stressing
② Stress due to eccentricity of pr. stressing
③ Stress due to bending moment.
④ Final stress after prestressing.

If it is seen that the beam will be under compression at top and bottom after pre-stressing with bamboo

If cross sectional area of bamboo strips are taken as 4 mm × 25 mm then number of strips required will be 17062 ÷ 100 ≈ 170





Equivalent cross sectional area of steel to be used at bamboo-to-steel grip is equiv. to 2133 mm². If the number of grips are used then area of each is 355 mm². safely 8×50 m.s. flats may be used for grip.

There is scope for development. The grip joint shown here is just the concept to convey.

If we think of Shaped Bamboo .....

grip joint and anchored.

• Concrete Columns pre-stressed with Bamboo strips.

Pretensioned Bamboo strips

Base plate

tensioned bamboo strips.

Column Section in plan

for large spans

• multilayered woven bamboo-cum floor similar to experiment already done with success.

very large span ?

Span suitable to Residential planning ~ 3500 ~ 4000

• multilayered woven bamboo roof panel stiffened with mortar in-lay.

M.S. flat welded for metal grip joint for conventional trusses where the tensile and compressive members designed may be used.

to bamboo

Small bamboo strips arranged to overlap exactly one on top of the other for all the layers.

flat nail

Layers

multilayered end view of the truss

• A multilayered Bamboo strip truss. Flat nail jointed based on distribution of force to a large number of tiny joints.

Bamboo strip

• A flat Chisel ended nail should cut across the grain of Bamboo strips and may thus be driven without pre-boring

Acute angle of safe use of the nail

Can we assume bamboo to timber plus steel divided by two? It has the quality of both and therefore, if the flexibility of steel in bamboo is supported by the rigid quality of mortar to act as one homogenic material will make bamboo behave like wood! Without applying the theory of bond and reinforcement, can we say 'mortar stiffened bamboo structure'! A multilayered stiffened bamboo structure should be strong enough to be called an efficient method of construction?

suspenders covered (wrapped) with W.P. sheet.

Split bamboo from thicker and large dia bamboos.

S

1500

6600

• A fully rainwater protected foot bridge truss.

Water proof cover - metal sheet, terracotta felt etc.

pressure from side with bolts for grip forces of suspenders.

Sec 'S-S'

Decking

metal wire grip

Corner notched with a round file

strip bamboo

Strips preferably from thicker bamboo

depth according to span.

• A simple light-weight frame for Roof cum ceiling.

Split Bamboo 2000

tensile bar

cross section

Line of mortar finish

woven bamboo strips

tensile bar 6mm ϕ.

tensile bar

tensile bar

3000

• pre-stressed panel module wall (to be plastered)

Filler piece

'U' bolt out of 8mm ϕ bar.

nut.

cross pin

3 nos of frame

View (A)

Controlled Cutting

straight Selected end bamboo

Controlled Spacing

Equal

Equal

Bamboo mat board.

Rainwater protective material

Composite bridge deck

double tuber shaped bamboo

thickness controlled

dia dia dia

varying diameter.

Few possibilities with strip bamboo. Conceptual sketches.